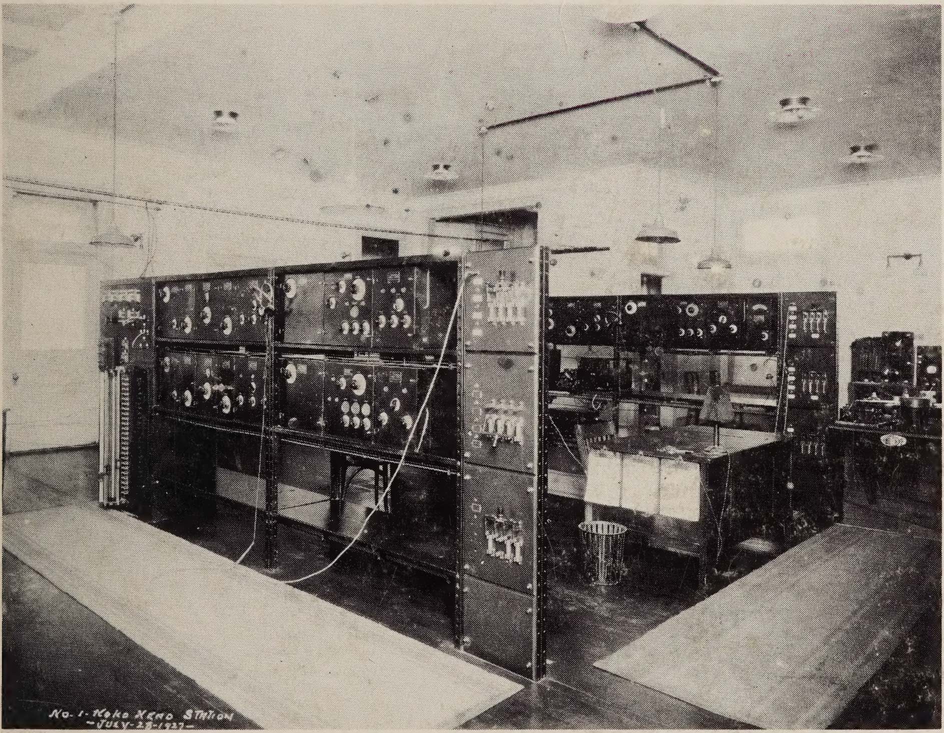
THE AWA REVIEW



Volume 6

Published by
The Antique Wireless Association

1991

THE AWA REVIEW

Volume 6

1991

Published By

THE ANTIQUE WIRELESS ASSOCIATION, INC.

Holcomb, N.Y. 14469

ANTIQUE WIRELESS ASSOCIATION, INC.

HOLCOMB, NEW YORK 14469

THE AWA REVIEW

Volume 6
First Printing, August 1991

EDITOR

Ludwell Sibley, KB2EVN
Flemington, NJ

OFFICERS of the AWA

President: Bruce Roloson
1st V. P.: Richard Ransley, WA2TLR
2nd V. P.: Bill Fizette, K3ZJW
Secretary: Joyce Peckham
Treasurer: Dexter Deeley
Curator of the Museum: Bruce Kelley, W2ICE
Attorney: Sherwood Snyder, W2KFU

THE COVER

Equipment room at the RCA Communications receiver site on Koko Head, Hawaii, as of 1927. See Robert and Tina Wiepert's article for more details.

Printed in the United States of America by
Sun Litho-Print, Inc., East Stroudsburg, PA 18301.

CONTENTS

FOREWORD

Our sixth annual issue of the AWA Review contains an unusual variety of historical material.

The lead article presents what was probably the first serious tube collection: the comprehensive samples collected by the radio-development group at the Washington Navy Yard and known as the Eaton Collection. A composite description by five authors covers its origins, contents, and untimely fate.

Examining an interesting episode in the history of the General Electric Company, John Anderson explores a corporate acquisition that fell through: the proposed purchase of Lee de Forest's manufacturing company. Regardless of the outcome, we get an informative picture of the de Forest company and its competitive position.

The early development of radio in the then-Territory of Hawaii is explored in a pictorial article by Robert and Tina Wiepert. Documentation of wireless history in the islands is not easy to find.

Pat Leggatt, a major force in the British Vintage Wireless Society, documents the development of television in the United Kingdom, from primitive disc scanners to color.

For those involved in the history of military communications-electronics, Frederick Chesson provides a comprehensive listing of U. S. Army Signal Corps equipment from before World War I to the early part of WW II. He has pieced together the identities of all known SCR-coded electronic systems (385 of them), RC-identified subsystems (289), and individual BC-numbered items (1093). His work relates the components to the complete systems, information hard to locate otherwise.

Most American historians "know" that Edwin Armstrong invented the superheterodyne receiver. However, Robert Champeix points out another contender - and not Lucien Lévy, the usual candidate - as predating Armstrong. We are indebted to Richard Foster for a skillful translation of the text.

Daniel McCoy provides a charming account of early amateur radio in the New York area. He was one of the teenage operators who pioneered amateur activity before WW I.

A history of electron-tube manufacture in Australia comes from Fin Stewart, long-time collector. He provides pictorial examples of tubes that reflect British, European, American, and local design influence.

Related to the McCoy article, Lou Moreau relates the far-reaching efforts of the communications industry and the amateur community to support the military/naval actions of World War I.

To conclude, David Kraeuter contributes a listing of the U. S. patents of eleven electrical/telephone/radio inventors. He cites 644 patents of inventors who were highly successful (Alexanderson), famous for other endeavors (Gernsback), or simply obscure (Stubblefield).

The Editor

THE EATON TUBE COLLECTION

1. THE STORY OF THE TUBE COLLECTION OF THE WASHINGTON NAVY YARD

George H. Clark

[From "Radioana" - SRM 52 299 - C.I. 5 596 100 179, February 27, 1938; now in the Smithsonian Institution. Copy originally supplied by Gerald F. J. Tyne.]

This collection for years hung on the wall of the Radio Test Shop, Washington Navy Yard. About 1929 I made sketches of the various tubes, for my collection of Radioana.

In 1933, I asked the Navy Department for a set of radio apparatus, of antique form, to display in the planned historical display of RCA at "A Century of Progress" [*the World's Fair of that year*]. Among other things, this tube collection was sent to me. It was exhibited in the original glass-covered case in which it came, and during my hourly lectures at the Fair I made especial mention of this historical relic. It attracted much attention, much more than other pieces of apparatus which were farther from the daily use of radio in the home.

At the end of the 1933 session of the Fair, I shipped this exhibit, with others of the Navy and my own collection, to New York for storage at our RCA Victor headquarters on 24th Street. It was planned to repeat the historical display at the Fair in 1934. But Mr. Joyce, of RCA Victor, vetoed this, and as RCA Victor had been given the job of getting up the exhibit at Chicago for all of RCA, his word was law. So, when I went to Chicago in 1934 to lecture, the historical display was left in storage.

In my absence in 1934, NBC made a raid on the entire historic collection. There had long been rivalry between NBC and myself as to who should be in charge of museum material, and while I was away, the head of my department, Glenn Tucker, "gave in" to NBC. So when I returned I found everything had been moved to NBC at No. 711 Fifth Avenue.

On returning, I made a fervent plea for the return of this material. My strongest point was that much of it had been loaned to me in person, as an old Navy employee, by the U. S. Navy and Army, and I had given a pledge to keep it my possession. This argument was upheld. At the same time, NBC began moving from 711 Fifth Avenue to Radio City, and could not take the collection with it, so I brought it back to its original status under me.

Room to store it was very kindly provided by Messrs. Sullivan and McConnach (respectively Comptroller and Secretary of RCA) in the RCA storeroom at 75 Varick Street, New York City.

In moving the apparatus back, I found, however, that much damage had been done to the items, while moving them to NBC or after they had been stored there. The interiors of many receivers, of historic value, had been looted for the "parts value" of the material; many smaller items, and the more priceless, had entirely disappeared (later appearing in the NBC display at Radio City); some apparatus had been smashed entirely.

Among the last named was the USN tube collection. It had not been packed in its original felt case, apparently, and when I found it at 711 Fifth Avenue every tube had been smashed to pieces.

2. THE EATON COLLECTION AND AWA

Bruce Kelley

The earliest vacuum-tube collection, to my knowledge, was the Navy grouping assembled by Lt. W. A. Eaton in 1918-19 and featured in Mary Texanna Loomis' 1927 book Radio Theory and Operating. Having been a tube historian since 1936, I was pleased to have an original photograph and additional information on the collection from an old friend, Ted Duvall. He gave me this account in 1959:

> "Between 1917-1919 I was employed as an Electrician, Radio 2nd Class, USNRF, at the Washington Navy Yard Radio Test Shop working directly under Lt. William A. Eaton, Radio Officer in Charge. Eaton was assigned the task of assembling a collection of all well known radio tubes of the period for evaluation. Some were supplied by the Navy, others by U. S. manufacturers and Allied governments. A few came from captured German apparatus.
>
> After the tubes were cataloged under the direction of Radio Expert Aide Lawrence Horle, fellow worker Raymond Shaffer and I were given the task of making a suitable display case. We made a 20" x 36" oak case 4" deep and lined with green felt. Shafer and I personally mounted the tubes and placed a hinged glass cover to protect them.
>
> On completion, a photograph was taken and a pamphlet written by Horle and approved by Eaton describing the contents. I was given one of the pamphlets, maybe because of my involvement in making the case and mounting the tubes. I am giving you [AWA] my copy for reference. Most of the tubes were common in 1918 but may be rare today."

Using Duvall's material, Lauren Peckham has identified the tubes further.

3. KEY TO THE PHOTOGRAPH*

Lauren Peckham

Although the original photograph of vacuum tubes contained in the collection was described by an accompanying table with a brief description of each (sheets 9 to 14 of a report coded RW50A267 and dated June 1919), historians of the 1991 period may desire additional information. In 1919 there was little need for lengthy explanations, and it is possible that such material as identifications of German types was difficult to obtain at the time. In addition, there were errors in some of the descriptions in the original key.

---

* *Photo: AWA Museum.*

1. British Marconi, Fleming two-element valve. Carbon filament. Cylinder plate, mounted directly on stem. Second-generation type with two-point bayonet base and side lead.

2. As 1 above. Carbon filament supported by glass rod, an attempt to provide a more rugged element structure.

3. Early experimental diode. Two carbon filaments; wire ring plate. Miniature two-point screw base with side lead. No further information available.

4. Early experimental triode. Carbon filament; wire ring grid and wire plate. Miniature two-point screw base with side lead. No further information available.

5. De Forest Hudson. Dual oxide-pasted carbon filament. Zig-zag grid supported on double seals; double plate on wire supports to seal. Miniature screw base; double end seal. Supplied with early de Forest apparatus.

6. Wireless Specialty (Pickard). Carbon filament. Perforated sheet grid supported from second seal. Bent sheet plate supported on wire from second seal. Both grid and plate are supported by the glass mount, which also carries platinum lead wires. Two-point skirted miniature screw base; double end seal. Crude experimental type.

7. De Forest tubular Audion, similar to Type T. Tungsten "V" filament. Heavy copper spiral grid, supported from only one end. Aluminum cylinder plate, fits bulb. Miniature screw base; double end seal. Used by Navy.

8. Later de Forest Hudson. Dual oxide-pasted carbon filament. Zig-zag wire grid on glass-rod support. Flat unsupported plate. Miniature screw base with double end seal. Used by Navy.

9. Moorhead Relay. Tungsten filament. Fine wire grid wound on glass frame. Continuous bent aluminum plate supported on the grid frame. Skirted miniature screw base. Single end seal with wires from base. Commercial.

10. De Forest, early version of CF-185. Twisted "V" oxide filament on spring support. Fine wire grid wound on glass frame. Aluminum plate on glass supports from end seal. Miniature screw base. Plate lead emerges from end seal; grid lead, from side tap.

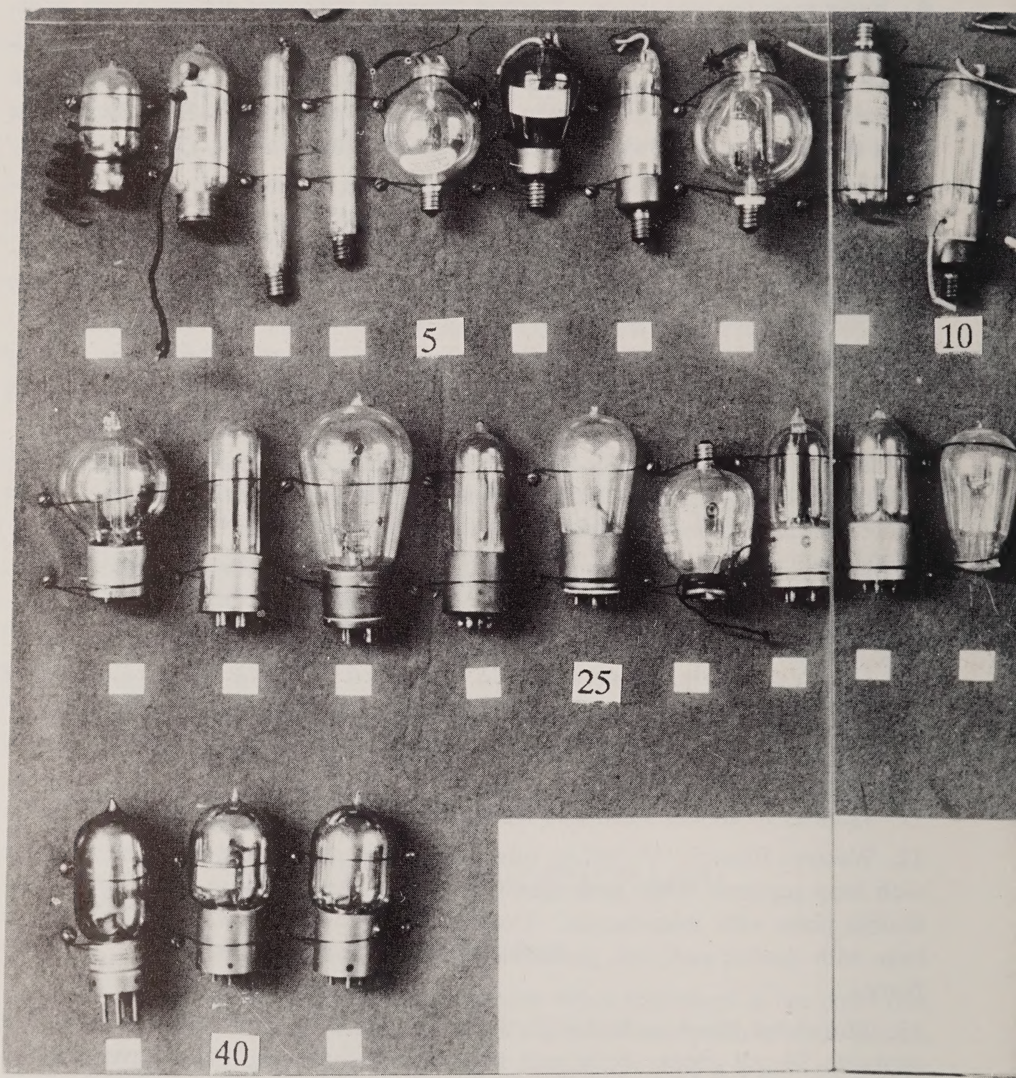
11. Same as 10 above. Plate lead comes through end seal; grid, through base.

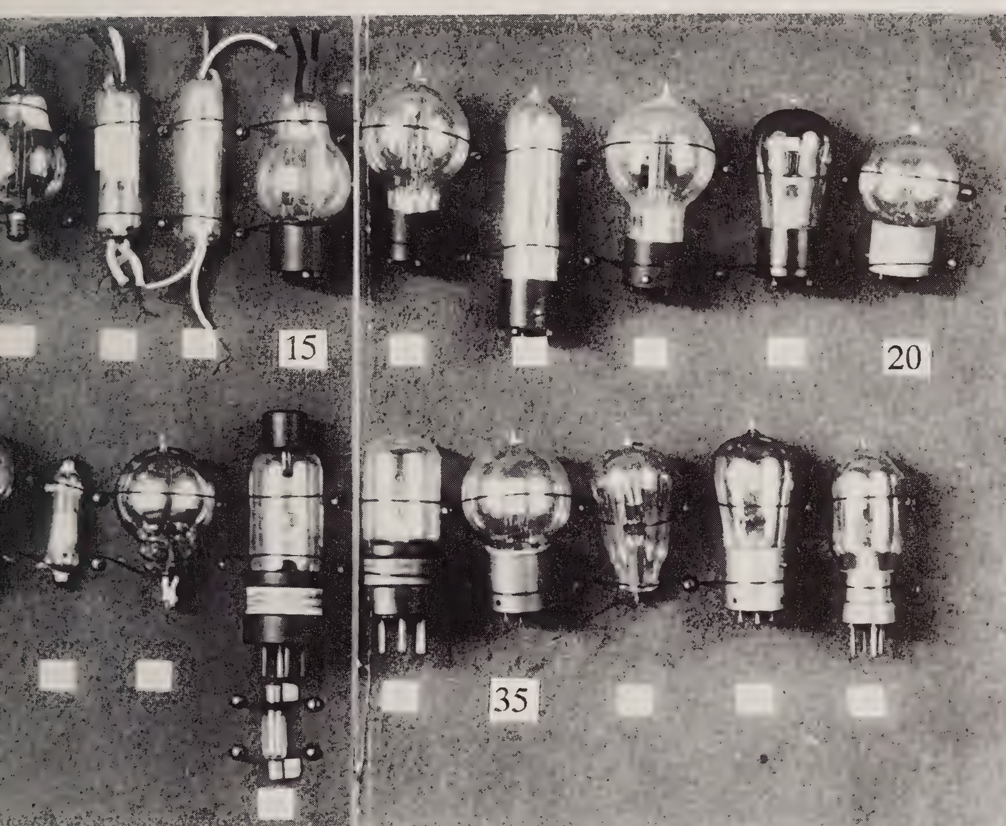
12. Western Electric "V" (102A) tube, early version. Twisted "V" oxide filament with loop support. Fine grid, spot-welded and supported on glass stem. Flat double plate with cross-breaks. Double-ended construction. Miniature screw base with double end seal, predating usual four-pin cast brass base. Used by Navy.

13. Moorhead Electron Relay (E. R.). Tungsten "V" filament with three-lead support. Heavy copper helix grid, supported at one end. Aluminum cylinder plate, fits bulb tightly for extra support. No base: plate and filament at one end; grid and two filament leads at other. Electrically very similar to 7.

14. De Forest, similar to 13. Straight tungsten filament. Heavy copper helix grid supported at one end. Aluminum cylinder plate, fits bulb tightly for extra support. No base. Plate and filament at one end; grid and filament at other.

15. Western Electric "V" (12) on Navy three-point base. [The Navy favored the


5
10
25
40



COLLECTION OF VACUUM RECEIVING TUBES
RADIO TEST SHOP
NAVY YARD, WASHINGTON, D.C. JUNE, 1919
RW 50A 267
SHEET 15.

three-contact base over the candelabra style, as replacement was faster and easier.] Twisted spiral "V" filament on loop support. Two flat plates, braced on both ends. Second seal for plate and grids.

16. De Forest, early version of CF-185. Twisted, coated "U" filament. Fine grid wound on glass frame. Two aluminum plates anchored to same glass frame. Three-point base. Navy standard.

17. De Forest. Tungsten "V" filament, anchored. Otherwise same as 16 using tubular bulb.

18. De Forest, another version of the CF-185. Twisted, coated, anchored "V" filament. Fine grid wound on glass frame with metal guards. Two flat plates, anchored at four points to glass frame. Three-point base. Navy standard. [Original key erroneously identified this as a Western Electric item.]

19. General Electric, CG-886. Tungsten double spiral headlight-type filament. Small thimble-shaped plate. Three-point base. Standard pliotron.

20. General Electric, variant of CG-886. As [19]; differs in shape of bulb, details of seal, and supports of grid and plate. Brass shell-type base, probably with three pins.

21. Western Electric "D" or CW-186. Twisted coated "V" filament, anchored. Fine welded grid, supported on glass stem. Double plate, braced to glass stem. Three-point base, made as wax-filled metal thimble. Former Navy standard. Also known as 201A, but not related to the later RCA UV-201A.

22. Moorhead. Straight tungsten filament. Rather heavy wire grid wound on glass, with copper guards. One-piece aluminum plate, anchored by glass frame. Four-point metal base with Micarta insulation. Sample is same as 9, but with four-pin base.

23. General Electric, CA pliotron. Special amplifier bulb. Tungsten "V" filament, anchored. Very fine grid, wound on glass frame, close to filament. Stiff fine-wire plate, in zig-zag form, wide-spaced, anchored at top and bottom. Four-point base. Tungsten wire used for grid and plate is similar to the design used by Irving Langmuir for his original pliotrons. High vacuum was possible due to relatively easy outgassing during processing, with minimal metallic surfaces.

24. Western Electric "J" (203A), original version with cast brass base. Twisted coated "V" filament, anchored. Fine wire grid, welded, and supported from glass stem. Double plate, braced from glass stem. Four-point metal base with Micarta insulation and wax seal.

25. General Electric CG-890 (see 19). Four-point metal-porcelain base. Sample has thimble-shaped plate, same as original CG-886. CG-890 was the Navy designation for the Signal Corps VT-11.

26. British Osram (G. E.) Type R4. Straight tungsten filament with bow support. Helix grid with bow support. Nickel cylinder plate with single transverse support. Miniature screw base. Bulb is actually single-ended, with leads brought along sides to candelabra base, same as de Forest spherical audion; all leads to tip seal.

27. Western Electric "J" (203A) or CW-933 (Signal Corps VT-1). Coated twisted "V" filament, anchored to lava block, with crossed tensioning springs. Coarse

stamped one-piece grid, with welded braces also tied to lava block. Double corrugated, welded flat plate, clamped onto stem. Plate holds lava block. Four-point metal base, wax-insulated.

28. Western Electric VT-3. Very fine twisted oxide-coated filament; two parallel sides anchored to a lava strip. "V" springs maintain tension on filament wires; also serve as leads through the glass press. Medium-fine wound grid, welded to wire frame, spaced close to filament. Flattened cylinder plate, welded to wire supports. Four-point wax-insulated standard base. Not Navy standard.

29. Horle-Harrison. Carbon filament. Wire grid on harp frame. Single, flat, unanchored plate. Unbased, regular lamp seal. Historical: probably the first valve made in regular lamp works.

30. French "Fotos." Straight tungsten filament. Helical grid, supported at two ends. Cylindrical nickel plate with center support. Four-prong French-British standard base. The bulb for which most foreign apparatus was built.

31. British "Q." Straight tungsten filament with spring anchor. Wire mesh cylinder grid, insulated from filament leads. Cylinder plate fits tube. Leads of elements terminated on metal contact caps. Patent No. 4410. Used in first stages of British apparatus. Has bulb similar to Marconi V24 but is not comparable.

32. U. S. N. experimental, first form of Moorhead SE-1444. Straight (Navy) tungsten filament. Helical grid, turns welded to support. Cylinder plate with one wire support, axial in bulb. Unbased, but with round bulb for four-point base. First step of new standard. (Cloth-covered leads were connected directly to binding posts.)

33. German, similar to Telefunken EVN 94 but with four-pin base. Carbon filament in form of a bow, ballast tube to go in series. Flat spiral grid, on glass supports parallel to plate. Circular disc plate on glass supports. Filament leads from upper seal go to large four-point base. From captured apparatus.

34. German, Telefunken EVE 173. Straight tungsten filament. Medium-fine cylindrical grid; stamped, bent, braced, and welded. Bent, cylindrical, braced plate. Large four-point base. A well made copy of 26 and 30.

35. Sample submitted by Moorhead. Double spiral tungsten filament. Coarse double spiral grid, close to plate, with two anchors. Cylinder plate, double-anchored. Four-point metal and Micarta base. A rejected step toward the standard tube.

36. Sample from Westinghouse, intended for use in transmitters and rated at five watts. Straight tungsten filament on spring supports. Helix grid. Cylinder plate on wire support. Unbased [most samples seen have a Shaw base]. Elements weak mechanically.

37. General Electric. Tungsten "V" filament, anchored. Helix grid, supported at ends. Cylinder plate with two welded supports. Four-point metal and composition base; five leads. Redesign of CG-890 with both ends of grid brought out to allow heating to aid outgassing during exhausting.

38. Moorhead sample. Straight Navy tungsten filament. Helix grid with turns welded to anchor. Cylinder plate, welded to "L" support. Four-point base of British type. Gold color of bulb indicates presence of phosphorous getter used

to obtain a better vacuum. Type number is VT-32.

39. Same as 38. Made by Moorhead, possibly Type C.

40. Moorhead. Straight end-supported filament. Helix grid, with turns welded to support. Cylinder plate welded to horizontal "L" support. Four-point metal and composition base. Bulb shape changed. Proposed as standard; horizontal plate and method of seal rejected.

41. Moorhead SE-1444. Straight supported filament. Helix grid, with turns welded to support. Vertical cylinder plate, welded to "L" support. Four-point metal and composition base. Plate and grid at opposite sides of seal. Adopted as standard.

4. VACUUM RECEIVING TUBES - REPORT ON COLLECTION OF VARIOUS TYPES

L. C. F. Horle

[From sheets 1 to 8 of the report coded RW50A267.]

This collection is composed of the various types of tubes that have been tested at this Laboratory, some of which have been used regularly in Navy practice, from the Fleming two-element valve (1) to the present standard tube [SE-1444] (41). Some of these were purely experimental; some are, or have been standard with foreign nations; and some have merely an historical interest.

Form of the Valve

In the two-element valve, the obvious method of construction seems to have been to use a common type of small lamp base, and add a side seal for the plate. The three-element valve, however, made the seal problem a more difficult one.

The early valves as shown in the original de Forest tubes (1-12), were usually provided with a miniature (standard "candelabra") lamp base, with the plate and grid leads brought out through a second stem sealed into the tip of the lamp.

In the "Electron Relay" of Moorhead and the tubes of de Forest, after which it was patterned, the first step is taken toward one-seal construction. In the de Forest (11), only the plate and the plate support are at the tip. In the Moorhead (9), all are at the base, two leads being brought out through the skirt.

It is to be noted here that in power tubes operating at high potentials, there is a good reason for keeping the plate lead away from the other connections for clearness of connections and safety in operation. However, development of small tubes continued along these lines; except that the other extreme, the baseless, tubular, double-ended form, arose, shown by de Forest (14) and Moorhead (13) again. This type of tube and mounting, however, was never standard in military or commercial service. This form of tube, however, has advantages over the previous types for detection and amplification, more so when constructed as in the British "Q" tube (31), which is quite efficient for the first steps of amplification, particularly at radio frequencies.

The three-point base soon followed. The base was made of insulating material, and some fairly modern efficient tubes were constructed on this base. This

involves, however, the use of the socket as part of the circuit, and the unreliability and irregularity of electrical connection through the "bayonet" pin led to the adoption of the four-point base.

The metal shell as a holder for the wax filling was the simplest method to permit the use of plastic insulating material, and later when the necessity arose of building tubes to stand high temperatures, as transmitting tubes in tropical climates, the porcelain construction (25) and the infusible molded-in-place composition were adopted. A disc of bakelite material held in place by spinning the metal over it was used for the later bulb CW-931, used mainly for transmitting.

The long-prong type is popular with the British and French, but is not as safe against displacement in service and open-circuiting of the contacts, and also has the serious defect that in spite of the unequal spacing of the prongs, it is possible to expose the filament to plate potential, instantly destroying it in most cases. With the bayonet construction, this is impossible, and transmitting and receiving tubes are also distinguished and non-interchangeable. This latter feature may become useless, as the recent tubes function admirably as either, but the safety features of the present standard base, especially in connection with the present approved forms of socket, made the insertion of a tube an absolutely simple operation.

Since, in radio-frequency amplification, the bulb capacity is found to be the limiting factor in short-wave work, and while, in practice, we have been satisfied with the results of keeping leads well spaced and small as in the present standard socket, yet there is very good reason for the form of the British "Q" (31) and some of the other foreign forms where the plate and grid leads are brought out widely separated, through independent seals. This method must be resorted to where extremely short wave operation is essential. Where a single type of tube is to be used throughout, it is undoubtedly true that our standard form is better practice.

Support of the Elements

Certain basic methods of supporting the element have come down the line of progress, and are worthy of notice. Support of plate elements by clamping around the stem, seen in the first Fleming valve, is revised in the W. E. Co. J tube CW-933 (27). Plate fitted to inside of tube, seen in (7), occurs again in 13 and 14 and the British "Q" (31).

A glass stem supporting the whole element is a W. E. construction, still used in their transmitting tubes (12, 15, 21); but is probably difficult to construct and is subject to breakage.

Glass-rod frames are used in a number of de Forest and G. E. constructions, and are convenient for the support of fine close grids. Very short sturdy welded supports from the seal were first characteristic of G. E. constructions (19, 20, 25, 27), making all these tubes very desirable from the standpoint of ruggedness. Lava and mica to support filament and grid from plate are shown respectively in 27 and 28. Glass to support the grid from the filament support is used in 31. The whole element is supported from the tip seal in 26, possibly an anti-capacity construction, but obviously undesirable.

The trend of all the changes is found to be back to the simplest, sturdiest construction. The standard tube SE-1444 (41) is almost the ruggedest, due to the L-

section of the plate support, without the sacrifice of electrical characteristics. It shows that the manufacturers, by attention to the problem, have succeeded in producing a tube of thoroughly satisfactory makeup with a minimum of deviation from the usual operations of sealing, etc.

Filament Construction

The earliest filament was, of course, the carbon, very inferior in emitting properties, because of its low working temperature. It probably would be practically useless at the high vacua of the later bulbs. The Hudson filament, supplied by the de Forest company in some of their early tubes, was coated for a small part of its length with an oxide paste, giving higher electronic emission on the Wehnelt principle, and was highly successful.

From this developed the oxide filament used by de Forest and later W. E. Co., consisting of a twisted flat strip of metal coated with a metallic oxide, and burned with a dull orange glow. This filament was used in many tubes of the CW-931 and CW-933 (27) types and their forerunners, and has the advantage of furnishing a plentiful supply of electrons, and at the same time giving a long life. With a filament of this type using but 0.2 amps, the tube (28) gives very fair results.

The tungsten filament occurs in two principal forms, the straight or bowstring and the double spiral, as the tendency is toward cylindrical plates, These are the forms that are suitable, although the V is used in 37. The double spiral is used in the G. E. tubes 19, 20, and 25.

The straight filament, however, with concentric grid and plates, used in some of the foreign tubes and finally in 41, almost invariably gives the best performance all-round as amplifier, detector and oscillator; especially in conjunction with its economical and simple construction as standardized. A slight wave is given the filament to prevent easy breaking by vibration. It is seen that the German manufacturers had copied this construction, and made a very rugged copy of it (34).

Plate

It is interesting to note that plate construction has reverted exactly to the form of the Fleming Valve (2). This is an outcome of the desire to obtain constant spacing between F, G and P at all points; and to utilize all the emission of the filament. The straight filament and cylindrical plate accomplish this very well. All others differ merely in the method of support, and since the energy to be dissipated is nil, the heat resisting properties are unimportant so that aluminum was used in Navy types. An interesting exception is the G. E. amplifier tube (23) in which the plate is a zig-zag of fine stiff wire about 0.003" thick. This is designed for extremely high voltage amplification and its effect is probably to diminish the capacity, but as a result the impedance of this tube is said by Miller to be of the order of a megohm. The thimble-formed plates characteristic of the early G. E. "Pliotrons" have been dropped on their own initiative, and the cylindrical form is being furnished under the same type CG-890 (37).

With tungsten filaments and plates of nickel, heated during exhaustion, tubes operate well as transmitters at high potentials (up to 1000 volts) and with plates quite red. Of course, the highest vacuum is necessary for such performance.

Grid

The grid or control element is first shown, in 3 and 4, as a ring of wire between the electrodes. In the first practical tubes, we have a wire zig-zag, which takes many forms later. In 6 the grid is of sheet metal with punched holes. This was very crude: the holes were large and round, and did not comprise a large proportion of the "grid" area; however, in 27 this method is well used.

The next types of grid were the wire wound on glass supports, the welded, and the helical. Wire-wound grids may be carried to the extreme of close spacing and fineness shown in the amplifier tube (23), very favorable to high amplification constant. Usually a metal covering is used over the glass rods to tie the turns of the grid, both electrically and mechanically. The fine welded grids of 12 and 21 made these tubes very efficient in their time.

Helical grids of the double-helix or return-wound type are used in the G. E. tubes (19, 20, and 25) and the "Meyer" tube (35) but have been abandoned with the similar type of filament. The simple helical grid is perfectly natural in connection with the cylindrical plate. In the French "Fotos" bulb (30) the helix is unsupported. In the British "Osram" (26) it is attached turn-by-turn to a stiffening wire by means of a fine tie wire. The German copy (34) has a grid which is stamped and bent, but exactly imitates a braced helix. In the last types of bulbs the grid turns are each welded to the supporting wire for a maximum of stiffness.

The German tube (33) is difficult to justify as either an efficient amplifier or an oscillator, and is probably merely a delayed step in development.

Spacing and Characteristics

Large plate spacing and small grid spacing favor amplification, while large surfaces and short paths increase the energy delivery. Hence a compromise is necessary. The later tubes are usually far more thoroughly exhausted, operating on a true electron-emission characteristic rather than a gas characteristic. This gives far greater uniformity, although in certain cases the gas tubes (usually of types 7, 9, 13, or 14) are said to have given startling results when only rectification is required.

The high vacuum in the new types is obtained by the use of a phosphorus or other "getter" in conjunction with the heating of the elements, either electrically or electronically. Both ends of the grid are brought out for this purpose in the G. E. tube (37).

The simple geometrical theory of the action of the tube presented by van der Bijl and developed by Miller indicates that the simple elementary form back to which the tube has found its way is correctly based on theoretical considerations, and that no great improvement is to be expected from changes in tube construction.

APPENDIX
DESCRIPTION OF VACUUM TUBES IN NAVY SERVICE

W. A. Eaton, Lt., U. S. Navy
Radio Test Shop, U. S. Navy Yard, Washington, D. C.

[A report coded RW50A254, February 3, 1919.]

RECEIVER VACUUM TUBES

TYPE CW-186

This tube was formerly known as the Western Electric type D. It has a spherical glass bulb and is provided with the Navy-standard three-point base.

Overall length: 4"; diameter: 2 1/4".
The grid elements are spaced 1/16" on each side of the filament.
The plate elements are spaced 1/4" on each side of the filament and measure 1-1/8" long by 5/16" wide.

The grid is fairly fine and has a mesh of 26 to the inch. The filament is of the helicoidal (twisted strip) V type with an oxide coating. It is operated at a dull-red to orange brilliancy at filament currents of from 0.9 to 1.3 amperes. The plate voltage should be from 70 to 100. This tube is a good detector of spark signals and a fair oscillator. It was a standard Navy receiver until about April 1918; it has since been superseded by the type CW-933. The CW-186 tubes were purchased from the Western Electric Company at a cost of $8.50 each.

TYPE CW-933

This tube was formerly known at the Western Electric type J. It has a cylindrical glass bulb and is provided with a Navy-standard four-point base. This vacuum tube has superseded the type "D" receiving tube. More of the CW-933 tubes are being supplied to the Service than any other type of receiving tube.

Overall length: 4-1/2"; diameter: 1-5/16".
Diameter of base: 1 3/8".
The grid elements are spaced 1/16" on each side of the filament.
The plate elements are spaced 1/16" on each side of the filament, and measure 1-1/4" long by 3/4" wide.

The grid is much more open than in the type CW-186 tube, having a mesh of 10 per inch. The filament is of the twisted-strip V type with oxide coating. It is operated at a dull-red to orange brilliancy, at filament currents from 0.9 to 1.3 amperes. The plate voltage should be 30 to 50 volts.

This type is not as good a detector of spark signals as the CW-186, but is a very good oscillator. When used in a regenerative circuit (with either inductive or capacitive feedback) it amplifies spark signals much more than any other tube. It is the best bulb known at the present time for use in audio-frequency amplifiers and is now being purchased from the Western Electric Company at a cost of $5.00 each. This tube is a very powerful oscillator and, when used for receiving radio frequency oscillations, is approximately 10 times as powerful as any other receiving vacuum tube. It is considered that this may be a disadvantage against the use of this tube in oscillating receivers. Reports on this feature are desired.

The average operating plate current for this tube is about two milliamperes.

TYPE CG-890

This tube is also known as the General Electric Type G pliotron. It has a pear-shaped glass bulb and is provided with the Navy-standard four-point base.

Overall length with the Navy base: about 4-1/2"; diameter: about 1-3/4".
The plate element is a cylinder, 1/4" in diameter and 4/10" long.
The grid element is a double spiral of 1/8" diameter with a mesh of 18 to the inch.

The filament is of tungsten wire and is of the compact helical type used in automobile head lights. The filament is operated at the brilliancy of an incandescent lamp filament with a current of 0.90 to 0.95 amperes. The filament and grid are practically enclosed within the plate element so that there is no objectionable glare. The normal operating plate voltage is from 20 to 40 volts. This tube is a good oscillator and a good detector of spark signals. The capacity between individual elements of the tube is kept as low as possible by separating the leads-in and insulating each one with a piece of glass tubing about 3/32" in diameter. This tube has a much lower capacity between the elements than any other tube now used. It is therefore very useful for short-wave work (below 300 meters). As an oscillator this tube is classed between the type CW-186 and the type CW-933. It is now being made in great quantities in the lamp factories of the General Electric Company and is being purchased at a cost of $3.50 each.

TYPE SE-1444

This tube is being manufactured by several manufacturers from Navy drawings. It has a pear-shaped bulb and is equipped with a four-prong base.

Overall length: 3-1/4"; diameter: 1-3/4".
The plate is an open nickel cylinder, 0.4" in diameter and 0.6" long.
The grid is helical, of 11 turns of 0.01 nickel wire, and 0.6" long.

The filament is tungsten, designed to operate at 4 volts and a current of 0.65 amperes. It gives best operation at a plate voltage of about 40, with a bias of 1.3 volts.

This tube compares very favorably with the CW-933 in its characteristics, although it is not quite as good an oscillator, but is quite as good in the reception of spark signals and is especially useful in radio-frequency amplifiers. It is expected that this type of tube will become standard in Navy service. At present the cost of these tubes is $3.05.

In addition to its use in receiving, this tube may be used with a plate voltage as high as 750 volts for transmission. When so used, it is capable of developing a power output of 10 watts. This makes it suited for telephone work and for low-power undamped transmission.

It is to be noted that this is the only bulb in Navy service which combines the functions of the transmitter and receiver.

TRANSMITTING VACUUM TUBES

TYPE CW-931

This tube is otherwise known as the Western Electric type E. It is used at present in airplane and other low-power sustained-wave transmitters. This tube has

a spherical glass bulb and is provided with a four-point base; the pins are arranged somewhat differently from the Navy standard base so as to eliminate the possibility of using any other tube in the socket designed for this type bulb.

Overall length is about 4-1/4"; diameter is 2-5/16".
The grid elements are spaced 1/16" on each side of the filament.
The plate elements are spaced 3/16" on each side of the filament, and measure 1-1/8" long by 11/16" wide.

The grid is rather coarse and has mesh of 10 to the inch. The filament is of the twisted-W type with an oxide coating. It is operated at an orange brilliancy at a normal filament current of 1.35 amperes. The normal filament voltage drop is 7.1 volts. The plate voltage should be from 300 to about 375 volts.

The normal space current is 40 milliamperes, at a plate voltage of 350 volts and filament current of 1.35 amperes. This tube is a powerful oscillator and is used only in transmitting sets.

TYPE CF-340

This tube is otherwise known as the de Forest 1/4-kW tube. It has a cylindrical glass bulb.

Overall length: 12"; diameter: 2-3/4".
Plate lead is brought off at the sealing end and the grid and filament leads from the opposite end.
The plates are spaced 7/32" on each side of the filament.
The grid is of fine wire with a 24-to-the-inch mesh.

The plate voltage is 1500 volts with an operating plate current of 150 milliamperes. The maximum permissible plate current is 200 milliamperes. The filament is of tungsten wire operating at incandescent-lamp brilliancy with a current of 2.4 amperes on 30 volts supply. It is used on de Forest 1.2-kW patrol-boat sets, the de Forest 1/4-kW aeroplane set, and de Forest 1/2-kW dirigible sets. These tubes are being purchased by the Navy from the De Forest Radio Tel. & Tel. Co. at a cost of $30.00 each. The General Electric Company manufactures a tube which is somewhat similar to the CF-340. The combined productive capacity of these two companies for this type of tube at the present time is estimated at 40 per week.

TYPE CG-1162

This is a General Electric tube, designed to be electrically interchangeable with the CW-931 of the Western Electric Co.

Overall length: 4"; diameter: 1-3/4".
Plate is cylindrical, diameter being about 0.35", and its length about 0.5".
The grid is helical, being built up in a double reversed helix.
The filament is similarly constructed.
The grid and the filament are supported only at their lower ends.

This tube is designed to operate on 350 volts on the plate and a filament current of 1.75 amperes at 7.7 volts. Under these conditions it delivers about 5 watts of power.

THE GENERAL ELECTRIC COMPANY CONSIDERS BUYING THE DE FOREST RADIO TELEPHONE AND TELEGRAPH CO., 1916

John M. Anderson
Scotia, NY

By the year 1914, Lee de Forest had been instrumental in the establishment of at least seven short-lived wireless telegraph or telephone companies [1]. The trail of bankruptcies which terminated these companies already had vaporized two sizeable fortunes, but this did not damp his spirit, for in the newest De Forest Radio Telephone and Telegraph Company (established January 1, 1914, capitalization $3,000,000) he saw visions of a third fortune. Indeed, this company seemed to be founded under more stable conditions than most of the earlier ones. Gone was the desire to establish a network of wireless stations in the face of heavy competition. He had received $50,000 from the American Telephone and Telegraph Company for "wire" rights to use the audion, and soon (October, 1914) was to receive $90,000 to extend these rights to "radio signaling." Yet another infusion of money came (April 8, 1917) in the amount of $250,000 from the Telephone Company for de Forest's circuit patents. This money came in addition to stock sales, permitting him a firm base to establish a laboratory and manufacturing facility at 1391 Sedgwick Avenue at High Bridge in the Bronx, and to begin and sustain the fabrication of wireless apparatus for amateurs and the Government. Audions were still purchased from the McCandless (lamp) Company, but beginning in 1914, de Forest installed vacuum equipment to make larger versions of the audion for transmitting, which tubes he called oscillions. He took a strong personal interest in both the financial and the technical sides of the Company, and the business prospered to the extent that sales for the year 1915 were approximately $130,000 [2] with $228,000 projected for 1916.

Yet de Forest was a restless soul. He had sampled research into the technical problems of combining sound with silent movies for a few months in 1913 while in the employment of John Lindley and his associates in New York City [3, p. 305]. Later, after World War I, this was to absorb his time and talents almost fully. He also became deeply interested in radiophone broadcasting, initially feeding 125 watts to an antenna on the factory roof and playing Columbia Gramophone records for his amateur fans. But, entering these new fields of interest to him would require considerable monetary drain from his existing business. Perhaps this realization, and the desire to change his line of work, caused him to entertain the thought of selling out to the General Electric Company in early 1916.

On March 10, 1916, E. P. Edwards, assistant manager of the General Electric Lamp Department (office in Schenectady, NY) and W. R. Burrows of the Edison Lamp Works, Harrison, NJ, visited the de Forest factory. Upon his return to Schenectady, Edwards wrote a "trip report" to A. W. Burchard, GE vice president in the New York office [2]. Shortly after the visit (March 13, 1916), de Forest rendered to GE a complete statement of the company's business for consideration. These two documents state the condition of de Forest's company in ear-

ly 1916 rather well, and bear looking at in some detail.

The De Forest Radio Telephone and Telegraph Company rented 10,000 square feet for $150 per month and was soon to expand into another 600 square feet under construction. It had 45 employees with a payroll of about $51,000 per year. Under normal conditions the president would have received $10,000 per year and the treasurer $2500, but these positions had recently become a game of musical chairs. Early in 1915 (April 23), Frederick M. Williamson was President and Treasurer and Lee de Forest was Vice President, Secretary, and General Manager. By December 2, 1915, de Forest was Vice President and Secretary and Charles Gilbert, Treasurer. Gilbert had joined the firm in July, 1915. Williamson had resigned the last week of November, 1915, leaving the presidency open.

A Statement of Assets and Liabilities dated February 29, 1916 gave assets as $3,004,495.44. Of this, the lion's share by far was $2,895,850.68 for patents and patent rights. The total of cash, accounts receivable, merchandise inventory, and machinery plus fixtures was $88,062.21. A deficit of $16,107.03 on January 1, 1916 and an additional deficit of $4,475.52 for January and February gave the sum of assets given above. (If this accounting of assets seems strange, it should be remembered that, at that time, each company devised its own way of recording assets and liabilities. Uniform procedures were only later established by the Financial Standards Accounting Board.) For the same two months the total factory cost was $43,212.06, while sales were only $38,736.54, accounting for the deficit. It may be of interest that a skilled mechanic (20 persons so classified) was receiving $25 per week, and two glass blowers a total of $45 a week, while the one radio engineer employed was paid $2400 per year (a weekly rate of about $46). It is amusing to note that the latter was classified as "unproductive labor," which of course is strictly correct as far as the bookkeeping is concerned. Also, the one sales manager was receiving $50 per week plus 10% of sales in excess of $26,000. It helps to visualize the extent of the operation to note that the inventory shows, among other items, totals of 10 lathes, six drill presses, one shaper, three milling machines, and 185 feet of bench space on the factory floor.

A list of unfilled orders (March 13, 1916) reveals to some extent the line of products manufactured and their list prices (per item).

3 ea.	RJ7 Receiver, list price	$200
13	RJ4 Detector	18
4	RJ10 Tuner	65
2	Combination Two-Step Amateur Amplifier	150
6	EJ1 Amplifier	60
2	V. C. 3-1/2 Condenser	35
4	RJ6 Receiver	110
39	RJ8 Detector	25
118	RJ9 Detector	14
2	600/4000 Meters Audion Ultraudion Receiver	800
2	6-inch Oscillion panel outfits	850
2	Coil	50
1	Receiving Cabinet	500

De Forest "Laboratory Oscillion" control panel. *Photos: Peckham colllection*

These items of equipment constitute the bulk of unfilled orders, which are broken down as:

Miscellaneous electrical concerns in the U. S. and amateurs..................$8665
United States Government $9950

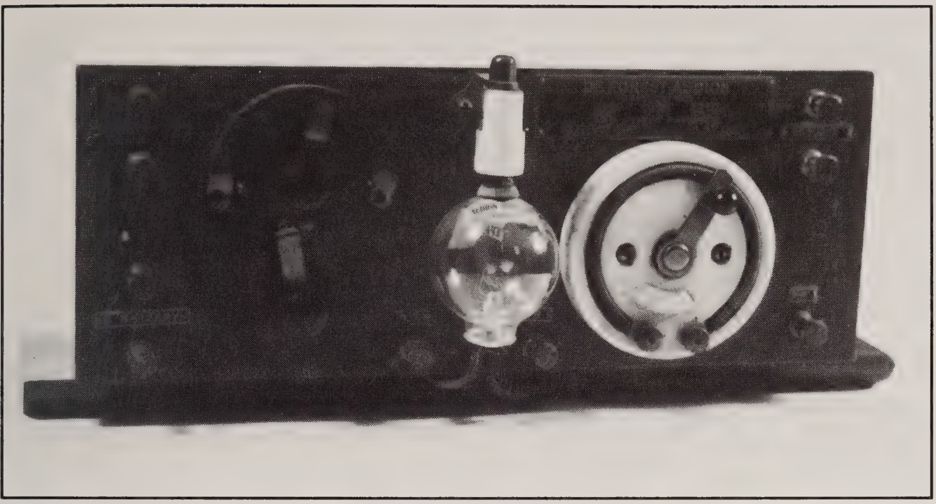
All of the above, although indicating a going concern of reasonable proportions with some growth potential, did not impress the General Electric Company. What they seriously sought were the patent rights for the audion. E. P. Edwards concluded [2], after his visit to the de Forest factory, that "Aside from the patents he owns, I do not believe that the Company has anything that would be of value to us and we would certainly not be warranted in purchasing it on the basis of its going value." This conclusion was punctuated earlier in his letter by

"The bulk of the heavy shop equipment is old and would probably be discarded in large part if we took over the plant. The exhaust pumps used in the manufacture of vacuum tubes is [sic] highly inefficient and would be of no value to us."

Specifically referring to the audions manufactured, Edwards comments, "Until recently the De Forest Company have [sic] been purchasing these from W. H. McCandless and Company. * * * The filaments are of drawn tungsten reinforced with tantalum, infringing our patent." At the time of Edwards' visit, about 50 audions were being produced per day. Their selling price ranged from $4 to $6, with an estimated gross cost to manufacture and sell of 50 cents each [2]. Further, W. R. Burrows (Edison Lamp Works) estimated the materials and labor of each audion at 20 cents and opinioned that, "There is no reason why any glass blower or small lamp maker could not engage in this business and sell the product at a price which would cut the De Forest business to pieces. * * * Temptation to manufacture these articles by irresponsible concerns will be great." [2]. How prophetic!

Edward concludes his attack on the audion with "The audion is used principally as a detector, probably 90% of the sales contemplate such use. Its life is very short, averaging 3 days, in the experience of the United States Government." Toward the oscillion he was only a little more laudatory: "It is comparable in size, but not performance, to our pliotron. The pliotron has an average life of 1000 hours and will operate continuously on 400 to 500 watts. The de Forest oscillion which we tested broke down at 40 watts." At this point he was most probably referring to tests conducted by W. C. White of the GE Research Laboratory in Schenectady [4] in the week of March 13-18, 1916. White had just received two tubular ultra-audions, one standard ultra-audion, one amplifier tube, and two large oscillions. The regular ultra-audion and amplifier had Hudson filaments. This regular ultra-audion gave blue glow (evidence of residual gas) at about 25 volts. The tubular ultra-audion, ". . . did not show b. g. [blue glow] even at 250 V E_p but the filament could not give emission enough because of its small size to run as a relay [amplifier] at this voltage." Concerning one of the oscillions, at 480 volts plate and 150 mA (72 watts) it developed blue glow and "relay action ceased." Note that this does not agree exactly with the 40 watts quoted above by Edwards, but it does compare favorably with the "50-watt" oscillion made by de Forest in 1915 [5, p. 118, Fig. 7-9].

It is perhaps necessary to step back in the face of such a blistering attack and realize that GE was looking upon the de Forest operation after its own laboratory had accumulated a good deal of experience with very high vacuum and had evolved some of the best (in those days) construction techniques for vacuum tubes. But it cannot be taken away from de Forest that, in the face of many problems, he still managed to make a usable product (within its limits), and his Company enjoyed wide sales. One can argue, of course, that the de Forest patents excluded others from such general sales. General Electric had too much to lose to risk a heavy settlement against it, and was, in fact, very careful not to sell directly, but rather loaned all equipment and vacuum tubes which left its premises. Other companies with little to lose were not so cautious. De Forest himself suspected that McCandless was bootlegging tubes [3]. Nevertheless, in the face of his critics, de Forest had always enjoyed, and did continue to enjoy, a good reception at the United States Navy Department. In the 1920s the De For-



RJ-5 detector, early version.

est Company became a major competitor for RCA tube sales (especially to amateurs), but finally, when it was on the rocks in the Great Depression, RCA bought its assets from receivership in 1933 [5, p. 301].

Returning to the patent situation, General Electric concluded that the de Forest patents probably dominated the amplifying feature of the audion, and that the detection feature was covered by the Fleming value, owned by the Marconi Company. But, regarding its use as an oscillator, "Dr. Arnold of the Western Electric Company thinks that the patent situation is open to everyone, so far as the 'oscillating' function is concerned, but both De Forest and Armstrong (Pupin's assistant) claim patent control of this feature, and I understand we have patents pending making similar claims." [2]. Marconi had secured an injunction against de Forest in 1914, claiming that the audion infringed the Fleming valve, but de Forest immediately appealed. When settled by court action on Sept. 20, 1916, the decision came down that both companies could not manufacture audions without the other's consent. The situation was further complicated by sale by de Forest of patent rights to AT&T. It would take only an agreement between Marconi and the Telephone Company to dominate tube sales without fear of infringement. The use of drawn tungsten wire for filaments was patented by GE, but Western Electric had oxide-coated filaments. At that time this appeared adequate. Had they not already transmitted voice across the ocean, Arlington, VA to Paris, in 1915 with oxide-coated cathodes?

General Electric concluded, "I do not believe that the purchase of the De Forest Company alone will clean it up [the patent situation], as we would still have to deal with the Marconi Company, owners of the Fleming valve patent, and it is my recommendation that we investigate the possibility of receiving a license under the latter patent before proceeding with De Forest negotiations. * * * Freedom, from a patent standpoint, to manufacture, sell and use the pliotron and kindred devices would be worth many hundred thousand dollars to us."

That GE did not buy the De Forest Company is a fact of history. Later that year, 1916, de Forest let it be rumored about that the Atlantic Communications Company (the American branch of Telefunken) was considering buying out his

company, and used this to his advantage [3, p. 340] to extract a final payment (April 8, 1917) from AT&T of $250,000 for rights to circuit patents, as said earlier. When the United States entered the war in 1917, all talk of patent rights ceased. Companies were kept busy supplying a large Government demand for tubes and equipment. After WW I, de Forest's personal interests turned to talking pictures, and in 1923, he sold all of his remaining stock in the company to Detroit industrialists [5, p. 300]. The name was changed to the De Forest Radio Company, and de Forest stayed on for a few years as an occasional consultant.

REFERENCES

1. T. L. Mayes, "De Forest Radio Telephone Companies, 1907-1920," copy in the AWA Museum library, Holcomb, NY; also available in T. L. Mayes, Wireless Communication in the United States (E. Greenwich, RI: The New England Wireless and Steam Museum, Inc., 1989), pp. 46-56.
2. Letter, E. P. Edwards to A. W. Burchard, March 30, 1916, AWA Museum library.
3. L. de Forest, Father of Radio (Chicago: Wilcox and Follett Co., 1950).
4. W. C. White patent notebook #630, General Electric Research Laboratory, pp. 303-306, AWA Museum library.
5. G. F. J. Tyne, Saga of the Vacuum Tube (Indianapolis: Howard W. Sams & Co., Inc., 1977).

John M. Anderson

John M. Anderson was born in Kansas City, Missouri and attended local schools until entering the U. S. Army in 1943. During World War II he headed a radio-transmitter maintenance team attached to the Army Airways Communication System. After the war he attended the University of Illinois, receiving a PhD in electrical engineering in 1955. In addition to regular studies, he worked as a research associate in the field of electromagnetic-wave propagation in ionized gases. In 1955 he joined the Technical Staff of the GE Research Laboratory and investigated in the areas of gaseous electronics, power circuit breakers, and electric-discharge lamps. For the years 1964-70 he taught plasma measurements at the Rensselaer Polytechnic Institute as member of the adjunct staff. In 1966 he was Chairman of the Schenectady Section of the IEEE. John retired from GE in 1987 and is presently engaged in consulting and researching early radio history. He is a Fellow of the American Physical Society and the IEEE. He also serves as Trustee of the Hall of History Foundation in Schenectady.

THE FIRST YEARS OF WIRELESS IN THE HAWAIIAN ISLANDS

Robert J. Wiepert
Tina M. Wiepert
Pearl City, Hawaii

INTRODUCTION

Ths article describes, through text and photographs, the evolution of commercial wireless in the Hawaiian Islands from 1900 to approximately 1930. During this time, four main companies were involved in the wireless field in Hawaii. Three were concerned only with transoceanic communication: the Federal Telegraph Company, the Marconi Wireless Telegraph Company of America, and its successor the Radio Corporation of America. The fourth, the Mutual Telephone Company, was involved in both transoceanic and interisland traffic.

The first Hawaiian use for wireless was for interisland connections. One of Mutual Telephone's predecessors, the Wireless Telegraph Company, undertook this endeavor with the help of the Marconi Company in 1899. Eventually service was established to all of the islands.

As for transoceanic communication, the Hawaiian Islands represented an important link in the completion of "worldwide wireless." The islands are strategically located between the west coast of the United States and the Orient. A high-powered station located here would have two vital functions: to work as a relay point for messages between the United States and Asia; and to serve as a land station for contact with ships of the steamer trade. The first company to realize this need was another predecessor of Mutual, the Hawaiian Telephone and Telegraph Company, in 1907. Federal Telegraph and American Marconi each arrived in the islands to establish its own stations in 1912.

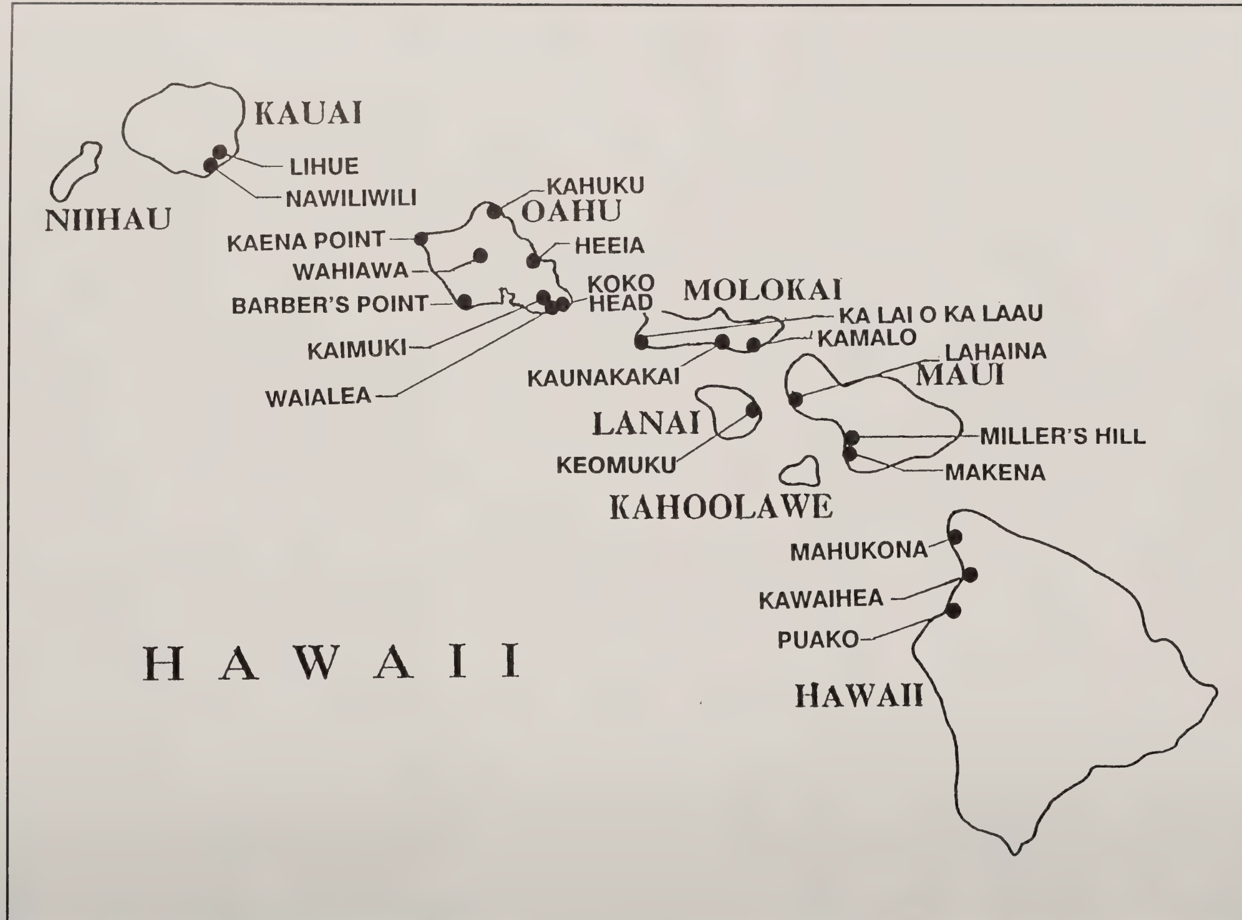
During World War I the Hawaiian stations were taken over by the United States Navy. Their military role will be touched on briefly.

The fourth company, the Radio Corporation of America, appeared in the islands as a direct result of WW I. As is well known, RCA was formed at the war's end for national-security reasons from the assets of American Marconi.

MUTUAL TELEPHONE CO.

The development of the Mutual Telephone Company's wireless stations, a process of trial and error, began at the turn of the century. In October 1899, F. J. Cross, the first manager of this system, was sent to New York to meet and contract with Marconi under the name of the Wireless Telegraph Company [1]. This contract called for the establishment of five stations on the islands of Kauai, Oahu, Molokai, Maui, and Hawaii.

Work began in April 1900 with the arrival of three of Marconi's engineers. The first stations were installed at Kaimuki, Oahu; and Keomuku, Lanai. When attempts to communicate between these two failed, it was decided that a relay site would be needed and a third station was erected at Ka Lae o ka Laau, Molokai. This third site could not reach either of the first two. At this point, attempts to


KAUAI
LIHUE
NAWILIWILI
NIIHAU
KAHUKU
OAHU
KAENA POINT
HEEIA
WAHIAWA
KOKO
HEAD
BARBER'S POINT
KAIMUKI
WAIALEA
MOLOKAI
KA LAI O KA LAAU
KAMALO
KAUNAKAKAI
LAHAINA
MAUI
LANAI
KEOMUKU
MILLER'S HILL
MAKENA
KAHOOLAWE
MAHUKONA
KAWAIHEA
PUAKO
HAWAII
H A W A I I

communicate among these first three were put on hold and three new stations were built at Makena and Miller's Hill, Maui; and Mahukona, Hawaii.

With the failure of the first three stations to communicate successfully, word was sent to Marconi. Andrew Gray, chief engineer of the Marconi Company in London, was sent to Hawaii to assess the problems. His first action was to move the Kaimuki station to Waialea, Oahu. This, along with other changes, resulted in contact between Oahu and Hawaii. These communications were irregular and relied on relaying through the stations on Molokai, Lanai, and Maui [2].

The next two sites to be erected were at Kaena Point, Oahu; and Nawiliwili, Kauai. These two could never communicate with one another. It was decided to move the Kaena Point station to Barber's Point, Oahu, from which contact between Oahu and Kauai was finally established.

The new installation at Barber's Point was also able to communicate directly with the Keomuku station on Lanai. This eliminated the need for the relay stations at Ka Lae o ka Laau and Waialea. The Waialea site was moved to Lahaina, Maui; and the Ka Lae o ka Laau station relocated to Puako, Hawaii. The Lahaina location could communicate directly with both Puako and Barber's Point, eliminating the need for Keomuku. The station at Miller's Hill was closed. Those that remained at this time were: Nawiliwili, Kauai; Barber's Point, Oahu; Lahaina, Maui; and Puako, Hawaii. This network of stations worked well and was reliable.

From the information available it was deduced at the time that the failures that had happened were caused by improper geographical locations and insufficient power at these stations.

In June 1907, John A. Balch and Clinton J. Hutchins purchased the Wireless Telegraph Co. from Mr. Cross for $50,000. At this time the company was reorganized. Balch became the vice president and general manager of the new firm. Under him the system was rebuilt with newer and more powerful equipment. In 1908 the organization's name was changed to Hawaiian Telephone and Telegraph Company [3].

One of the first things done was the building of a new station on the island of Molokai. A small installation was erected at Kamalo, allowing direct communication with that island for the first time since the station at Ka Lae o ka Laau was removed.

Late in 1907, the management of the system realized that there was a need for a new, more powerful site on the island of Oahu, able to communicate with steamers at a distance at least 1000 miles. However, they lacked the experience to build it. To meet their needs, they acquired the services of Arthur A. Isbell from the mainland. Isbell's previous career included working with Reginald A. Fessenden; operating the radio on the S. S. President, the first wireless-equipped commercial vessel to sail around Cape Horn; and being the Pacific Coast agent for the Massie Wireless Telegraph Company [4]. Mr. Isbell devised and built a new station at Kahuku, Oahu, by September, 1908. The first night the Kahuku station was in operation, communication was established with the United Wireless Telegraph Co.'s installation on Telegraph Hill, San Francisco, giving the first radio communication between the Hawaiian Islands and the mainland. With the completion of this station, the old station at Barber's Point was dismantled.

1908 STATION LIST FOR HAWAIIAN TEL. AND TEL. CO. [5]

Name	Island	Call	Power (kW)
Barbers Point	Oahu	BP	1
Nawiliwili	Kauai	NW	½
Lahaina	Maui	LH	1
Puako	Hawaii	KA	1
Kamalo	Molokai	AM	½
Kahuku Point	Oahu	HU	15

On August 2, 1909, the Hawaiian Telephone and Telegraph Co. was purchased by Mutual Telephone Co. and the name changed accordingly [6].

In 1910, the station at Puako, Hawaii was moved to Kawaihae, Hawaii; the installation at Kamalo, Molokai, was moved to Kaunakakai, Molokai; and in the autumn of 1912, a new site was built at Lihue, Kauai, to replace the one at Nawiliwili. This station opened on Election Day, November 5, with the first regular message received being "Wilson sweeps the country."

1912 STATION LIST FOR MUTUAL TELEPHONE [7]

Name	Island	Call	Power (kW)
Kahuku Point	Oahu	HU	2, 10
Lihue	Kauai	NW	2
Lahaina	Maui	LH	2
Kawaihae	Hawaii	KA	2
Kaunakakai	Molokai	AM	½

With the building of the trans-Pacific communication station at Kahuku, Oahu, by American Marconi (covered below), it was decided to move Mutual's Kahuku station to Wahiawa, Oahu. The Wahiawa station opened on March 5, 1914 and allowed night communication with Pago Pago, Tutuila, American Samoa; Apia, British Samoa; and Suva, Fiji [2]. This system remained the same until the start of WW I. On April 6, 1917, the Wahiawa station was taken over by the U. S. Navy; the others, on April 8.

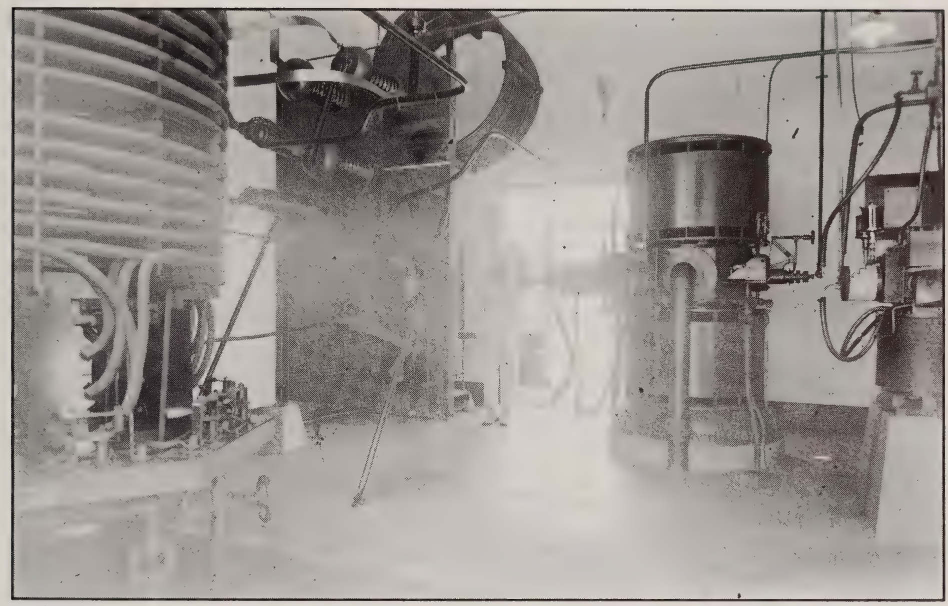
1917 STATION LIST FOR MUTUAL TELEPHONE (U.S. NAVY) [8]

Name	Island	Civilian Call	Power (kW)
Wahiawa	Oahu	KHK	2, 10
Lihue	Kauai	KHM	2
Lahaina	Maui	KHL	2
Kawaihae	Hawaii	KHN	2
Kaunakakai	Molokai	KHO	½

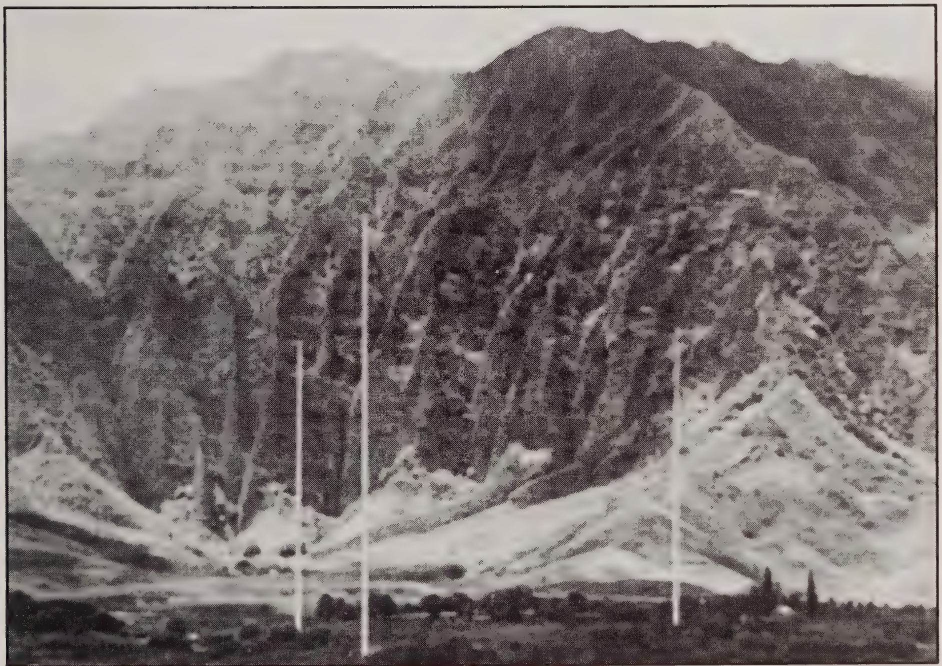
After the war the stations were returned to Mutual [8]. They remained in operation until late 1931, when they were replaced by short-wave radiotelephone stations built by RCA [9].

FEDERAL TELEGRAPH CO.

The Federal Telegraph Company from California was the first company to in-



Arc room in Federal station at Heeia, 1919. Far left: antenna loading coil. Center: rotary wavelength-changing switch. Right: 100-kW arc converter.



Towers at Heeia: two 440-ft, one 608-ft. Looking into Ioleka'a Valley.

stall a high-power station in the Hawaiian Islands for only trans-Pacific communication (between Hawaii and San Francisco). It was installed at Heeia Point, Oahu. The site was in operation, for nighttime contact only, by August 1912 [2, 10, 11], competing with existing submarine telegraph facilities.

The original antenna for this station was 40,000 feet of seven-strand phosphor-bronze wire placed between two wooden towers 440 feet high and 600 feet apart [10]. The original transmitter consisted of a Federal 30-kW arc system designed and built at the plant at Palo Alto [11].

In January 1914, a third antenna mast of 608 feet was erected and a 100-kW transmitter was installed to replace the 30-kW set. This gave service day and night [11]. This station was in service until April 6, 1917, when the Navy took it over. It was purchased by the U. S. government as of May 15, 1918 [8].

Under the Navy a makeshift 25-kW arc set was installed, principally for ship work using the call KHX. This and the 100-kW arc set were operated by remote control from the Marconi station, also under Navy control, at Koko Head, Oahu [8]. This station was used to communicate with the shore stations at San Francisco, San Diego, Tutuila, and Guam. It also worked ships enroute from Honolulu to the United States, Samoa, New Zealand, and Australia.

The Heeia Point naval radio station was in operation through WW II, at which time it was used as a listening post to determine the activities of the Japanese fleet.

AMERICAN MARCONI AND RCA

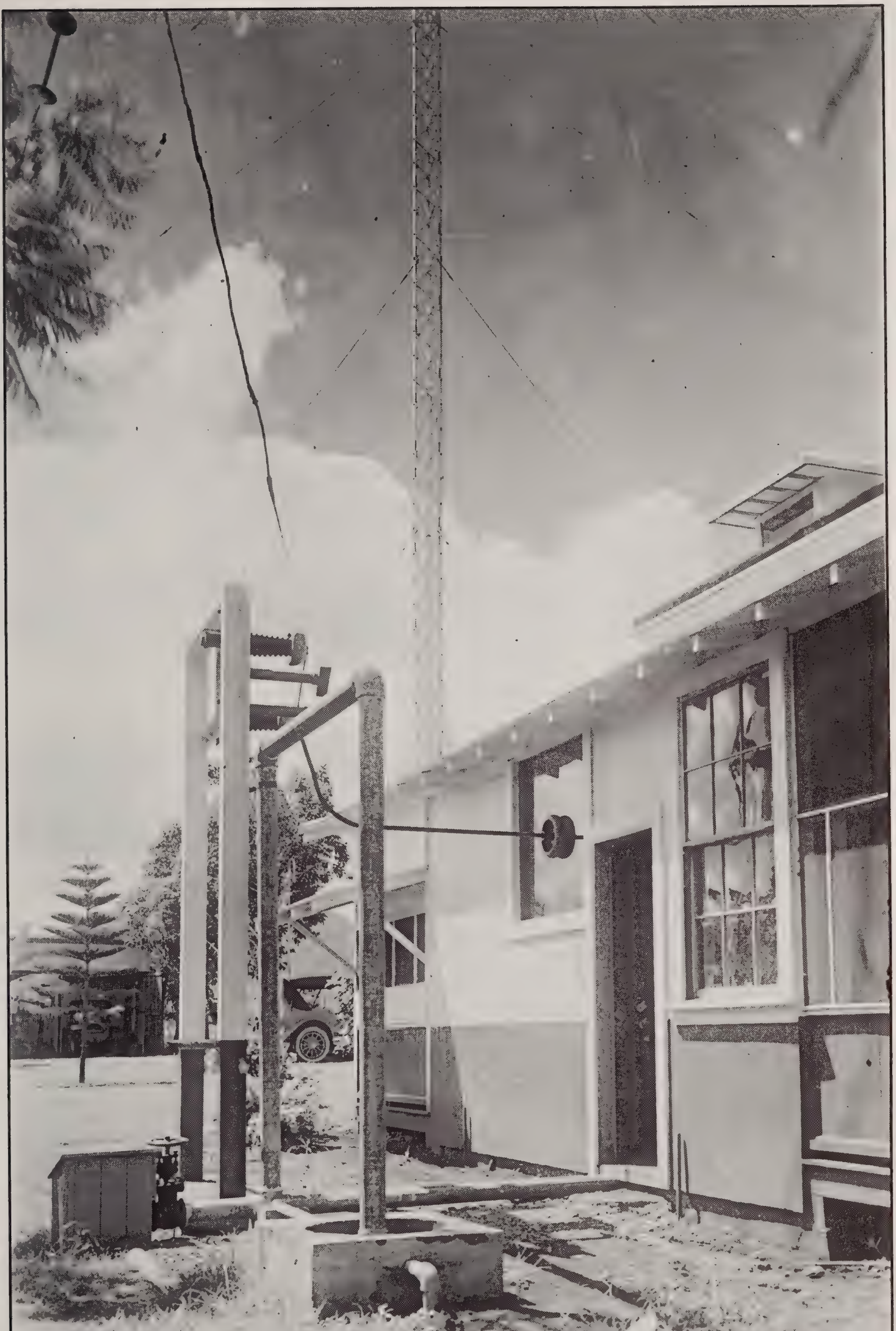
American Marconi's first experience with Hawaii was with the building of the interisland wireless system used by the Mutual Telephone Company, as described earlier. By 1912, Marconi realized the importance of a high-power wireless station in Hawaii. In August 1912, F. M. Sammis, chief engineer, arrived on Oahu. He located a site at Kahuku for the installation of a 300-kW (400-hp) synchronous spark transmitter on 9415 meters (32.8 kHz) to link with the stations in Bolinas, California and Funibashi, Japan [2, 8].

At its opening, the Kahuku station was claimed to be the largest wireless station in operation. One reason for the size was the need for its own power plant, since power was not available on the north shore of Oahu. The station consisted of four main buildings: the power house, the transmitter building, the engineer's office and the hotel for workers and guests.

The transmitter was connected to two aerials. The first, for San Francisco, consisted of twelve steel masts, each 325 feet in height. The second, for Japan, was also constructed of twelve steel towers but 475 feet in height [12]. With the remoteness of Hawaii, the masts for these aerials had to be shipped to the island in sections and assembled on-site.

The station's opening was accompanied by a large celebration, beginning with a special train loaded with guests. These dignitaries included the Governor of Hawaii, Mr. Pinkham. At the luncheon, the governor depressed a telegraph key, setting the station in operation. That day messages were exchanged with President Woodrow Wilson, Mayor Rolph of San Francisco, and several members of the President's cabinet [10].

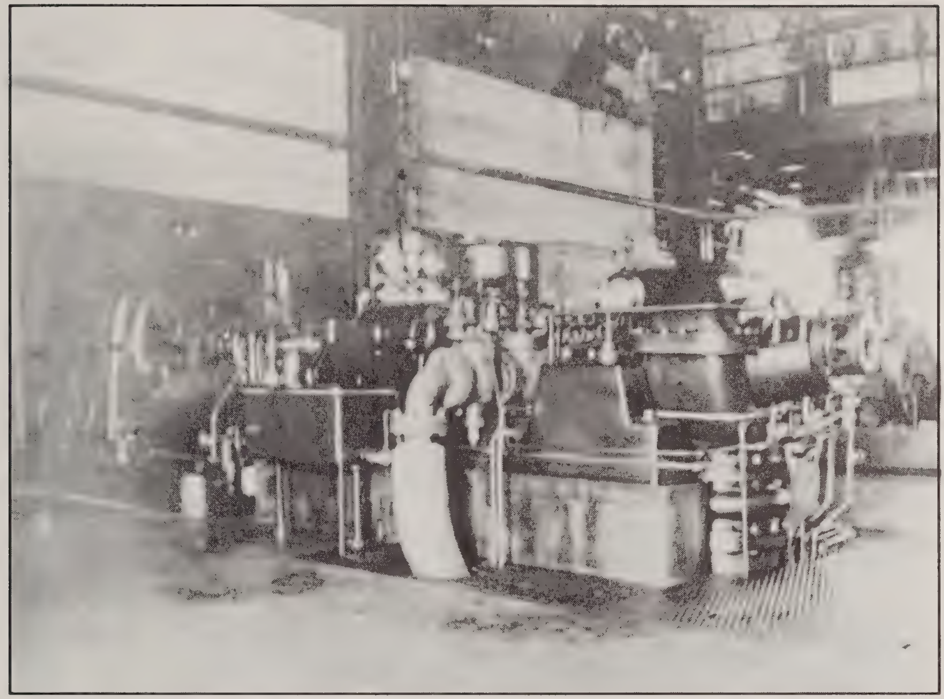
For receiving and for remote control of the Kahuku station, Marconi constructed a second site on the southeast end of Oahu at Koko Head. Work began

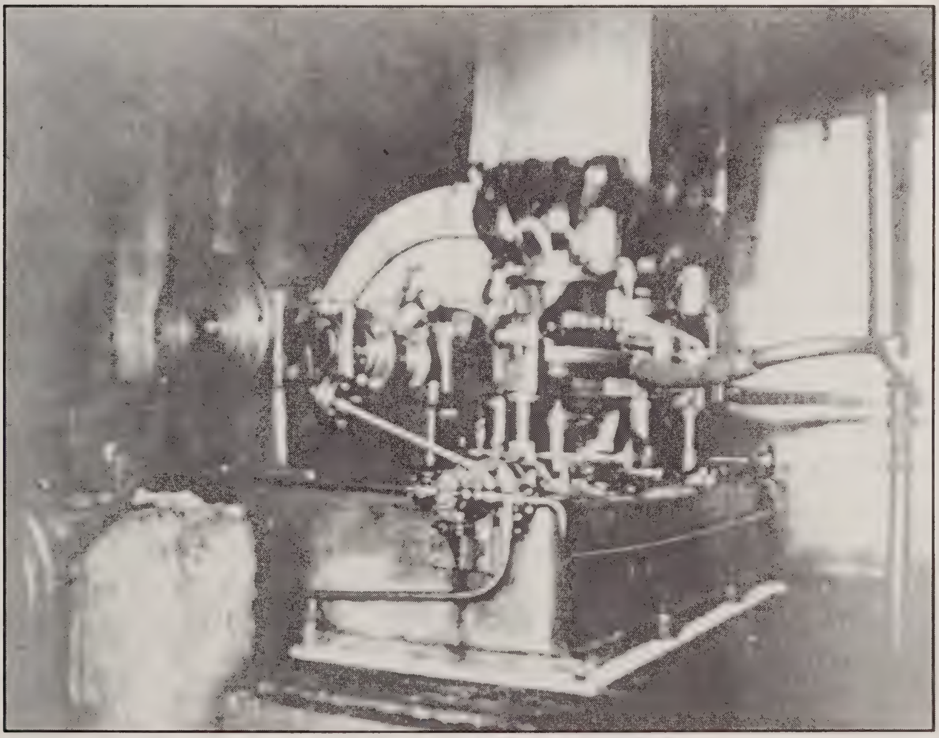


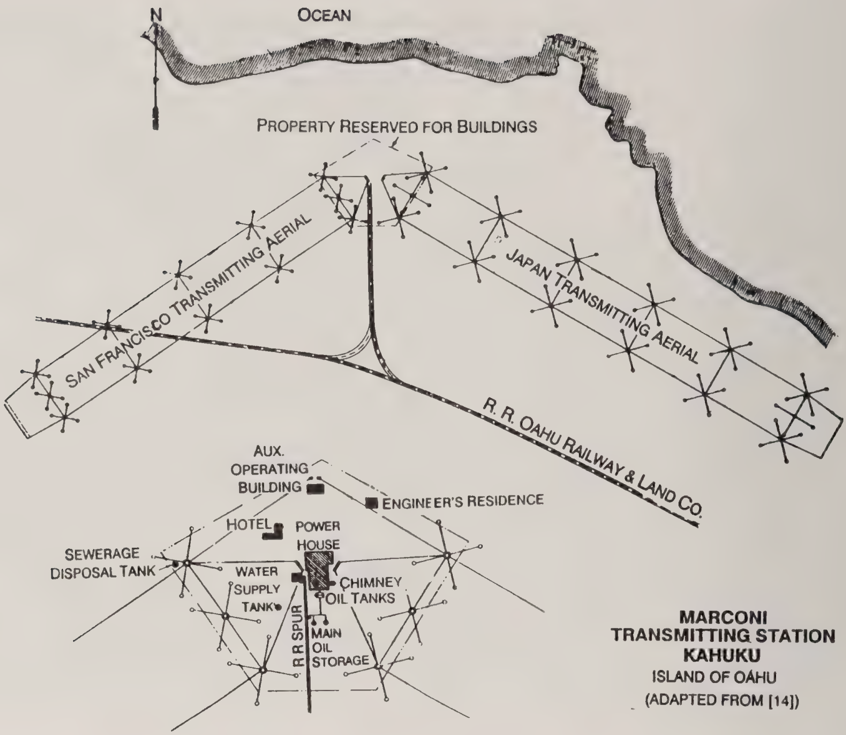
Grounding switch and "gas seal" (wall feed-through?), Federal/Navy station at Heeia, 1919. Contemporary auto in background.


Heeia station, ca. 1918. The white building is the transmitting facility.

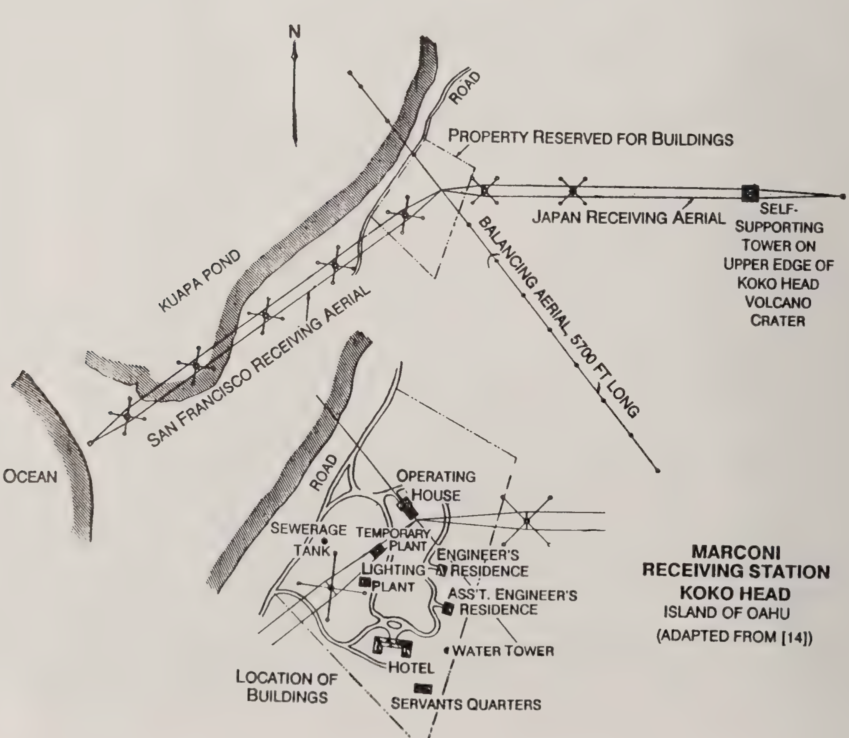

American Marconi station at Kahuku, under construction ca. 1916.


Marconi installation at Kahuku, ca. 1916, showing the 300-kW long-wave synchronous spark-gap transmitter.


The five-foot rotary gap in its cork-lined sound-absorbent room.

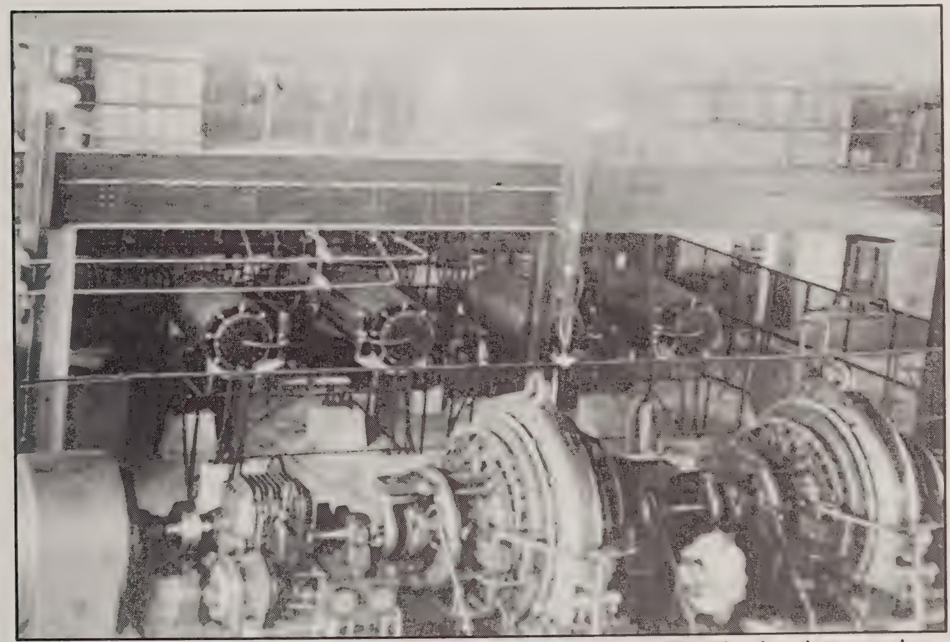


MARCONI TRANSMITTING STATION KAHUKU
ISLAND OF OAHU
(ADAPTED FROM [14])

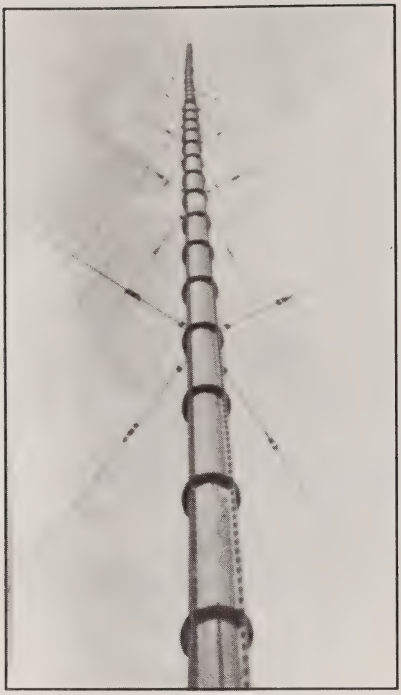


MARCONI RECEIVING STATION KOKO HEAD
ISLAND OF OAHU
(ADAPTED FROM [14])

Installer at Kahuku and the stator of an Alexanderson alternator, ca. 1920.

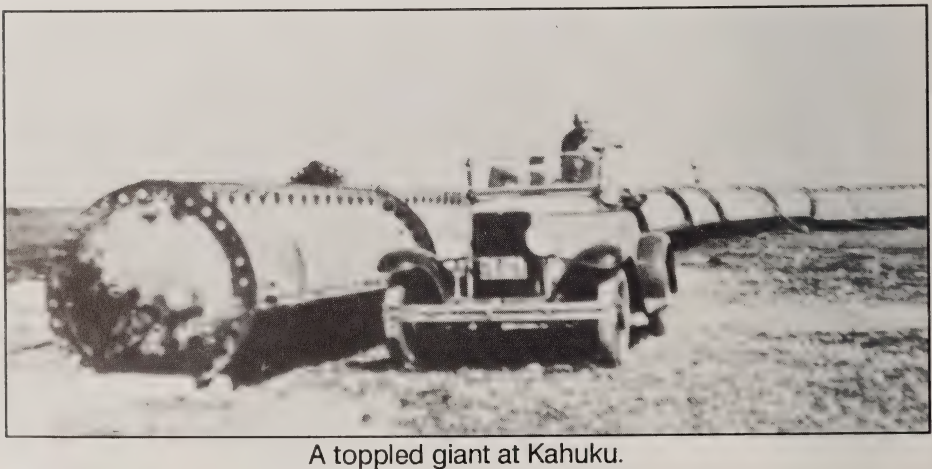


Machine gallery with the two alternators; tuning coils in the background.

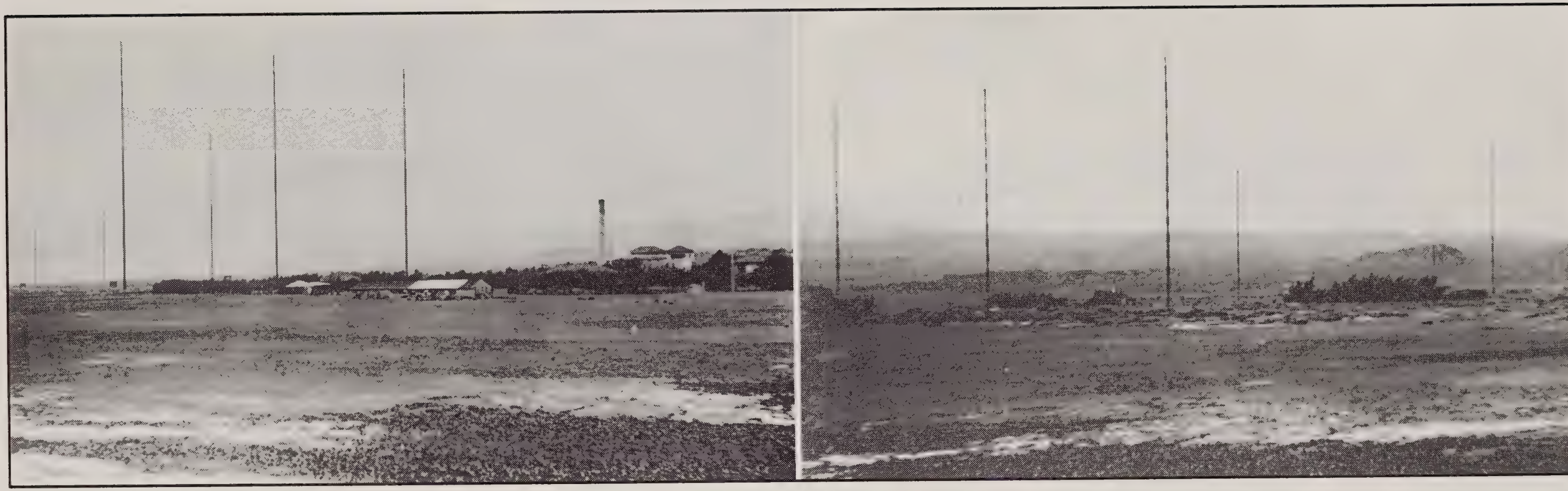


Sectional guyed tower, built for shipment to the islands, at Kahuku ca. 1916.

Demolition of the ex-Marconi long-wave towers by RCA, ca. 1930.



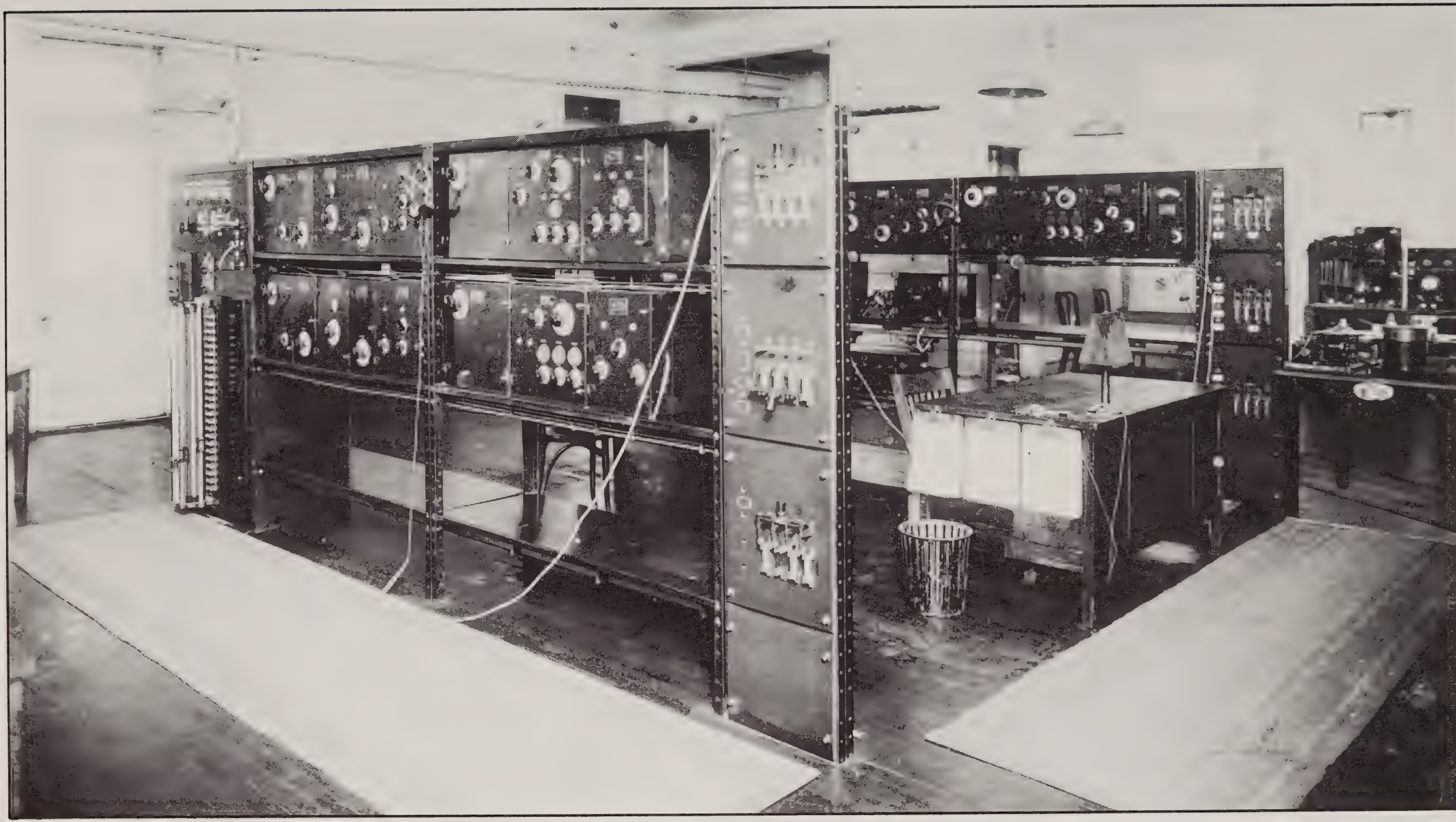
A toppled giant at Kahuku.



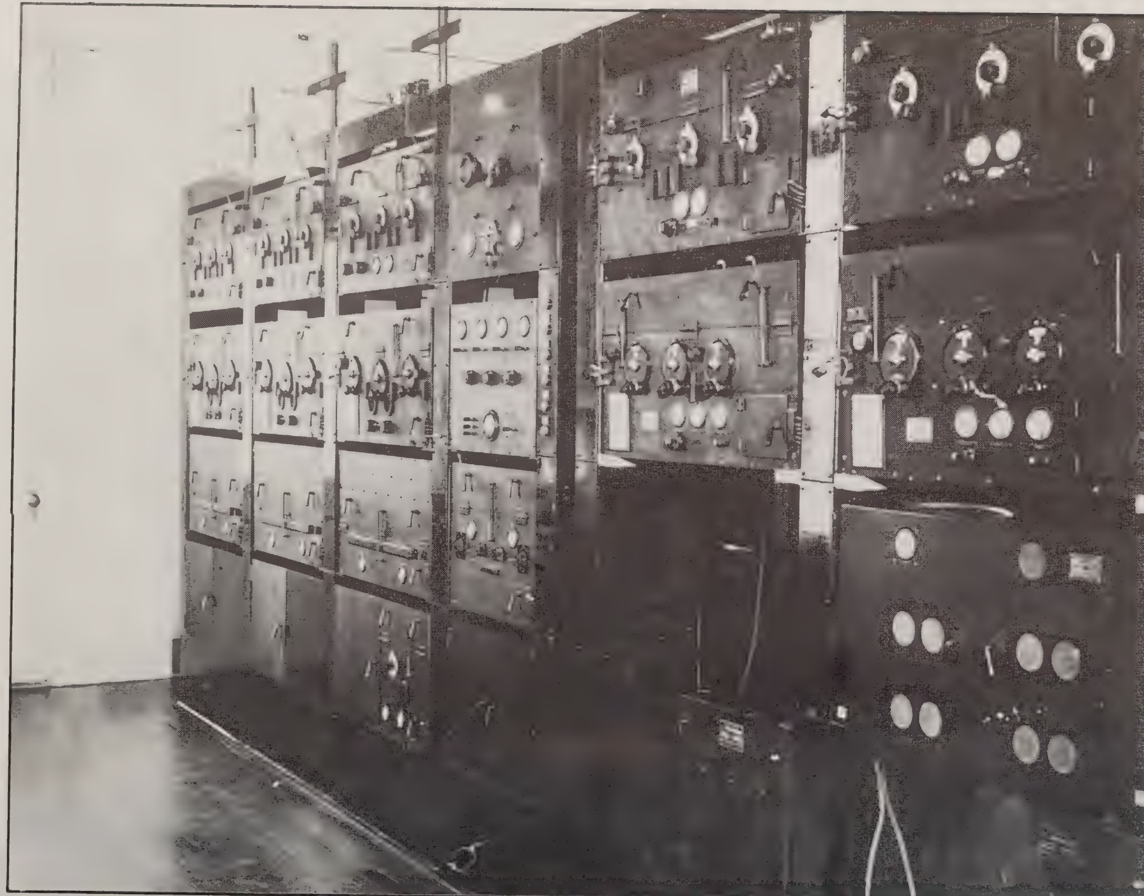
Panoramic view of Kahuku, ca. 1920: Japan antenna and transmitter building on left; San Francisco antenna on right.

Hotel at Marconi/RCA Koko Head station, ca. 1920.

Station house, antenna, and Koko Head; ca. 1920.

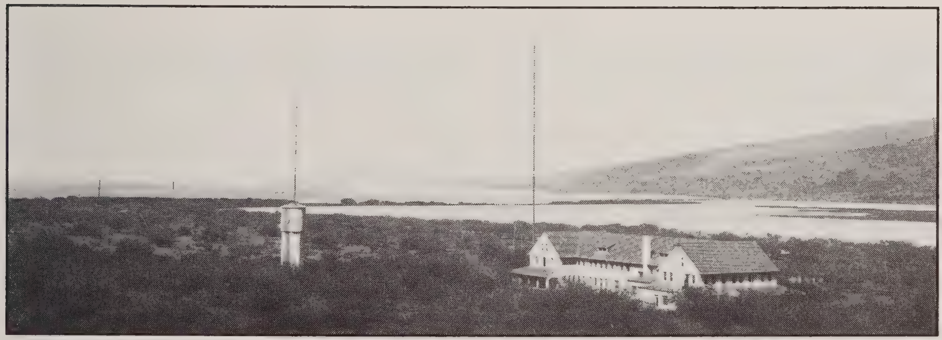


RCA receiver room at Koko Head, 1927. (Compare with Riverhead station, <u>AWA</u> <u>Review</u> 5, p. 12.)

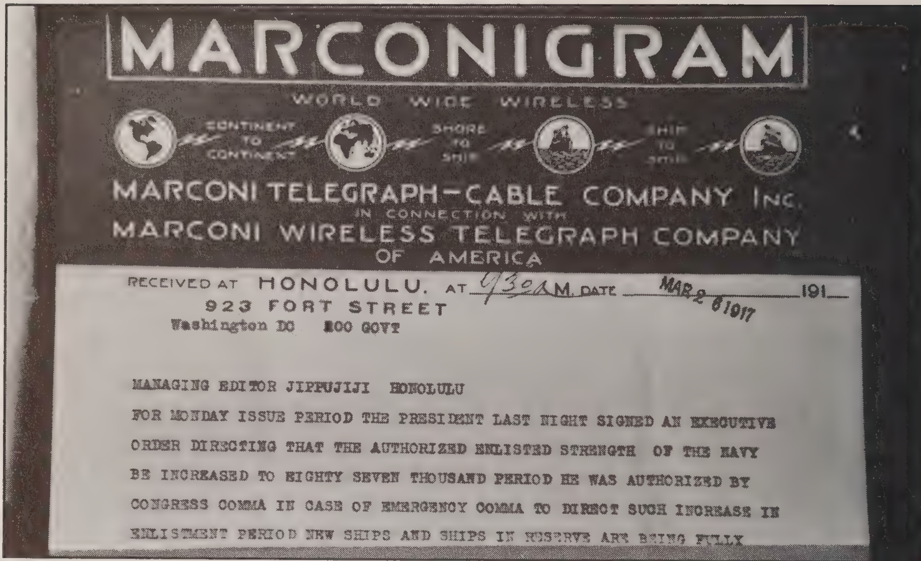


Koko Head receiver room, after 1930s modernization.

Koko Head station, 1930s. Telegraph testboard at left. RCA-style line amplifiers at center. Western Electric 13A oscillator and line bays at right.



Koko Head hotel and towers.



MARCONIGRAM

WORLD WIDE WIRELESS

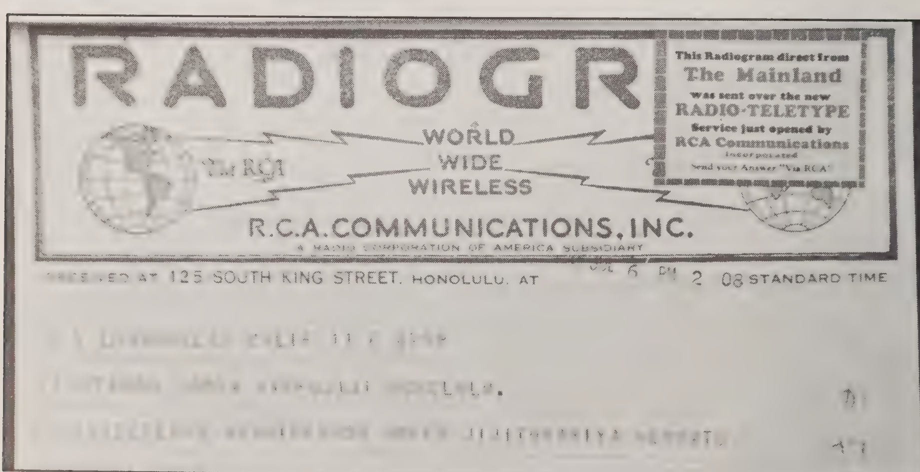
CONTINENT TO CONTINENT — SHORE TO SHIP — SHIP TO SHIP

MARCONI TELEGRAPH-CABLE COMPANY INC.
IN CONNECTION WITH
MARCONI WIRELESS TELEGRAPH COMPANY
OF AMERICA

RECEIVED AT HONOLULU. AT 932 A.M. DATE MAR 26 1917 191
923 FORT STREET
Washington DC 800 GOVT

MANAGING EDITOR JIPPUJIJI HONOLULU
FOR MONDAY ISSUE PERIOD THE PRESIDENT LAST NIGHT SIGNED AN EXECUTIVE
ORDER DIRECTING THAT THE AUTHORIZED ENLISTED STRENGTH OF THE NAVY
BE INCREASED TO EIGHTY SEVEN THOUSAND PERIOD HE WAS AUTHORIZED BY
CONGRESS COMMA IN CASE OF EMERGENCY COMMA TO DIRECT SUCH INCREASE IN
ENLISTMENT PERIOD NEW SHIPS AND SHIPS IN RESERVE ARE BEING FULLY

Press traffic received at Koko Head, March 26, 1917.



RADIOGR

WORLD WIDE WIRELESS

R.C.A. COMMUNICATIONS, INC.
A RADIO CORPORATION OF AMERICA SUBSIDIARY

This Radiogram direct from The Mainland was sent over the new RADIO-TELETYPE Service just opened by RCA Communications Incorporated Send your Answer "Via RCA"

RECEIVED AT 125 SOUTH KING STREET, HONOLULU, AT 6 PM 2 08 STANDARD TIME

RCA radiogram, July 6, 1932, pasted-up from strip teleprinter.

RADIOGRAM

INTER-ISLAND AND SHIPS AT SEA

THE PIONEER INTER-ISLAND WIRELESS COMPANY OF THE WORLD

MUTUAL RADIO

OPERATED BY THE MUTUAL TELEPHONE COMPANY
MAIN OFFICE AT 1128 ALAKEA ST. HONOLULU, T.H.

JUN 27 AM 7 55

2 KHK MC 9 JFYC SS TATSUTAMARU VIA WAHIAWARADIO 27TH 732A

Mutual Radio message, June 27, 1932, also by printer.

in the summer of 1913, and included the building of the station house, a large hotel, and numerous small utility buildings.

The aerials at this station were similar to the ones at Kahuku, except that the towers for the Japan circuit were 430 feet high and the end of the aerial wire stretched to the top of Koko Head, an extinct volcano, a span of 2000 feet [12].

These stations performed in commercial service until the start of WW I. The Kahuku station was taken over by the Navy on April 6, 1917 and was operated under the call KIE. The Koko Head station was taken over on January 3, 1918 and operated under the call KHJ [8].

During WW I, the Navy thought that the Kahuku spark station produced so much interference between 4000 and 8000 meters that it should be closed down. It was felt that the only military value it had was as a generator of interference against enemy ships or stations [8]! The Koko Head station, on the other hand, was of considered of great value to the Navy, for it used this station for distant control of the Pearl Harbor spark and arc sets and the arc set at Heeia. There were two telegraph circuits (keying lines and order wires) to the Heeia Point station, two to the Pearl Harbor station and three spares. Koko Head was used to receive from San Diego, San Francisco, Tutuila, Guam, Cavite, and Funibashi; and from ships equipped with arc and spark sets.

Neither of these stations was thought to be needed by the Navy after the war, so they were turned over to the newly formed Radio Corporation of America on March 20, 1918. Under RCA, two 200-kW Alexanderson alternators, serial numbers 9 and 10, were installed in 1920, the first at a wavelength of 16,120 meters (18.6 kHz) and the second at 16,667 meters (20.0 kHz) [13].

In the early 1930s RCA brought down the masts of the massive longwave antennas at Kahuku, the last of the original Marconi equipment.

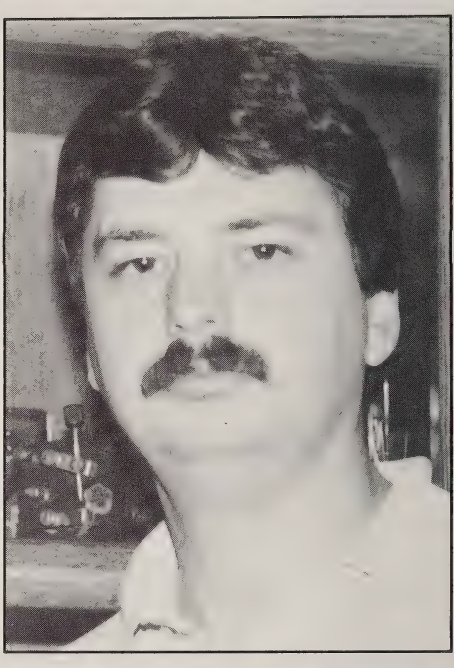
ACKNOWLEDGEMENT

The authors would like to thank Bill Moore, Manny Perez, Leslie Leigh, and Bungi Kashiwagi, all retired RCA employees, for their cooperation in supplying the information to produce this article.

REFERENCES

1. William A. Simonds, The Hawaiian Telephone Story, (Honolulu: Star-Bulletin Printing Co., 1959), p. 30.
2. L. W. Branch, "Evolution of Wireless Telegraphy in Hawaii," *Paradise of the Pacific*, December, 1915, pp. 72-75.
3. As [1], p. 33.
4. Thorn L. Mayes, Wireless Communication in the United States (E. Greenwich, RI: The New England Wireless and Steam Museum, Inc., 1989), p. 79.
5. Letter from J. A. Balch, Wireless Telegraph Co., to W. F. Frear, Governor of the Territory of Hawaii, August 25, 1908.
6. As [1], p. 37.
7. As [5], August 12, 1912.
8. George B. Todd, "Early Radio Communications in the Fourteenth Naval District, Pearl Harbor, Territory of Hawaii," essay (Honolulu: Tom Throm, 1985).

9. As [1], p. 71.
10. "Reminders of the Past," *Honolulu Star-Bulletin*, April 29, 1969.
11. M. A. Mulrong, "Radio In Hawaii," Hawaiian Annual, 1929, pp. 66-69.
12. "One Link In Wireless Chain," *Paradise of the Pacific*, March, 1917, p. 22.
13. As [4], p. 182.
14 E. E. Bucher, Practical Wireless Telegraphy (New York: Wireless Press, Inc., 1917), pp. 298-299.



Robert J. Wiepert

Robert J. Wiepert was born in Lackawanna, New York, a city just outside Buffalo, in 1960. He received a Bachelor of Electrical Engineering degree from Gannon University in Erie, Pennsylvania. He was hired out of college by the Sperry Corporation, now Unisys, as a field engineer working on defense contracts throughout the United States. His interest in radio began from the knowledge he gained in working in his father's TV and radio repair shop while growing up. Today Bob specializes in collecting early and rare tubes and pre-1928 radios while living in Hawaii.

Tina M. Wiepert

Tina M. Wiepert was born in Lackawanna, New York, in 1961. She completed two years at Gannon University in Erie, Pennsylvania, and was married to Bob in 1982. Now living in Hawaii, she works as an accounting clerk for a major construction supply firm. Tina's hobbies, besides her interest in radio and radio history, include collecting old teddy bears. Her interest in radio has led to the establishment of a Hawaii-based group of AWA members and to other research projects.

A REVIEW OF EARLY TELEVISION IN THE UK

Pat Leggatt*
Crondall, Farnham, Surrey, England

ESTABLISHMENT OF THE BASIC PRINCIPLES

The communication system requirements for television are not dissimilar in principle to those for radio, except perhaps that the necessity for a linear link is not so fundamental in the television case. The development of radio-frequency generation, transmission and reception techniques for sound broadcasting served, in general, for television transmission developments.

The early technological problems of television centered firstly on the conversion of data from a two-dimensional area object into a single serial data stream, and vice versa; and secondly on the required opto-electrical transmitting and receiving transducers. Solutions for the first category of problems were established as early at 1843, when Alexander Bain published his ideas for a facsimile system. This included simultaneous horizontal and vertical scanning of the object surface, together with measures for synchronizing the receiver scanning with that of the transmitter. The transmitter transducer was based on electrical contact of a stylus, so the object surface had to be describable in terms of the presence or absence of electrical conductivity: printer's type metal was an original application.

At the receiving end the electrical signals were passed to a stylus which was scanned over the area of a sheet of paper. The paper was moistened with a chemical solution which discoloured with the passage of current, thus reproducing an image of the original object surface.

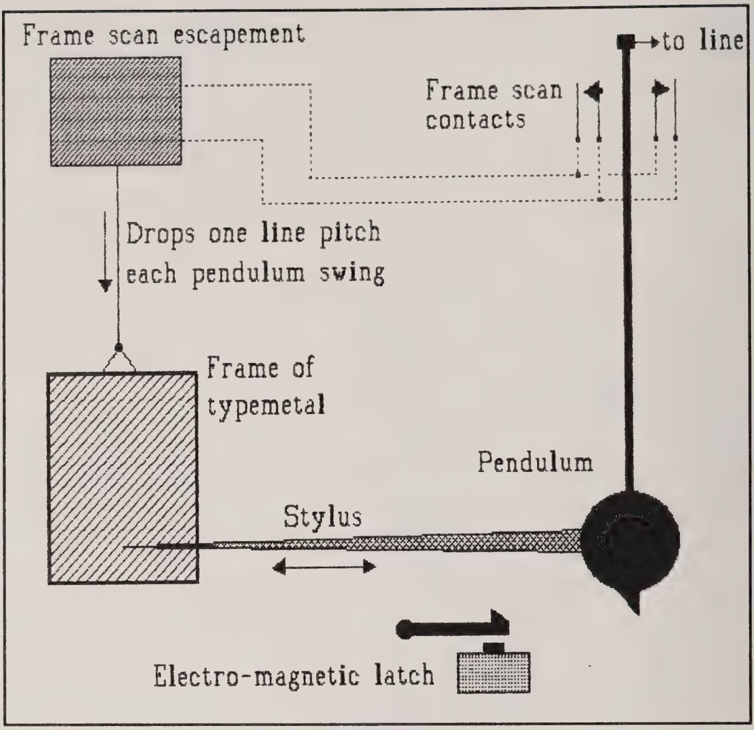
At the transmitter and at the receiver, line scanning was controlled by pendulums, coupled to escapement mechanisms to provide frame scanning. A synchronizing signal was arranged to delay the latched release of one pendulum if it got ahead of the other. These scanning and synchronizing principles were almost identical to those employed in television today, except that today's television receiver frame scan is initiated by separate synchronizing signals rather than as a count-down from the line scanning. Even here the principles are not all that different since the field and line synchronizing pulses in a modern studio center are derived from a common standard frequency source.

These early systems did not embody optical sensors and cannot therefore be classified as television: true television had to await development of suitable electro-optical transducers. At the receiving end some sort of solution became possible in the 1920s with the advent of valve amplifiers, in that the intensity of a neon discharge tube could fairly readily be modulated. The necessary scanning could be accomplished with the aid of Nipkow discs, or with oscillating or rotating mirrors.

At the transmitting end also a solution was available in principle, since photoelectric effects had been known for many years, in particular the photo-conduc-

---

* Adapted by the author from his paper in the *1989 Supplement to the Bulletin of the British Vintage Wireless Society*, pp. 7-11. ©1989 BVWS. Reprinted by permission. *Photos: Pat Leggatt.*



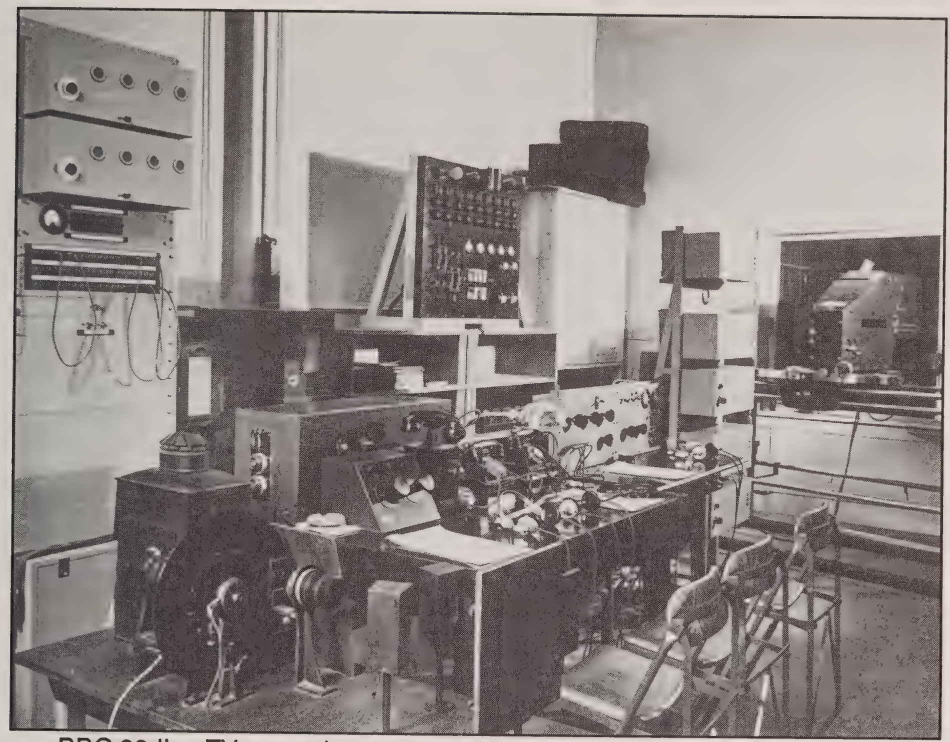
Bain's facsimile apparatus.

tive properties of selenium. Thus, in theory at least, the chain was complete by the mid-1920s and the only things still needed for a practicable television system were improvements to the sensitivity, colorimetry and speed of response of the camera transducer; development of scanning systems affording finer structure and higher picture repetition frequency; a transmission link of adequate bandwidth and phase response; and a larger, brighter display device. Yes, that was all!

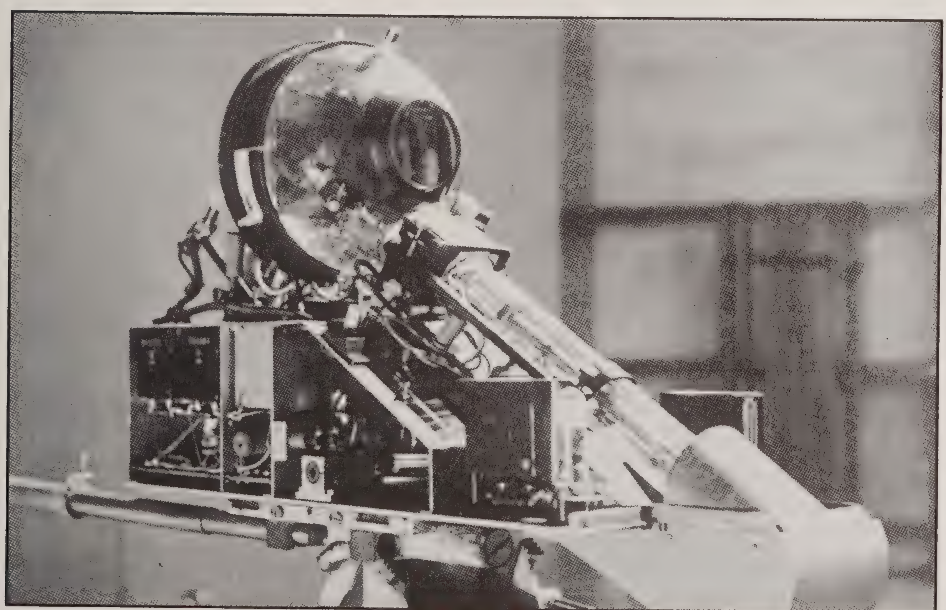
MECHANICAL VERSUS ELECTRONIC DEVELOPMENT

The cathode ray tube had been invented by Braun in 1897 and a number of workers saw the potentialities of an electronic approach to television. Rosing and Campbell-Swinton were notable proponents of this in 1911, but the technology did not then exist for their well conceived ideas to be put into practice.

The field was left open therefore to development along mechanical lines. John Logie Baird commenced his work on television in 1923, giving the first successful demonstration of a complete system in October 1925. Similar work was being done at about the same time in America and Germany. Mechanical scanning systems, although cumbersome, were adequate enough for the undemanding 30 lines/12-½ pictures per second standards of this early television, and were indeed used for the BBC's regular experimental transmissions from 1929 to 1935. But a system for satisfactory public service required much higher picture definition and better movement portrayal, and the Baird system was finally pushed up to 240 lines/25 pictures per second. These in fact were the standards defined in the UK by the 1934 Selsdon Committee as the minimum acceptable for broadcast-



BBC 30-line TV control room, 1934. Left to right: sound rack, caption machine, two radio-picture receivers, flying-spot camera. Chairs are for sound engineer, program director, and vision engineer.



Emitron television camera with cover removed.

ing, whereas they represented about the maximum which could be achieved by Baird's techniques. The situation was in some ways comparable to the early days of radio carrier generation, where the upper frequency limit of electro-mechanical alternators was soon reached and where further progress had to depend on electronic developments.

In fact there were two fundamental limitations in Baird's system. First, as already stated, there was the upper frequency limit of scanning systems depending on rotating discs or moving mirrors; and indeed Baird's 240-line installation at Alexandra Palace (north London) in 1936 included an electronically scanned device in the shape of the Farnsworth Image Dissector.

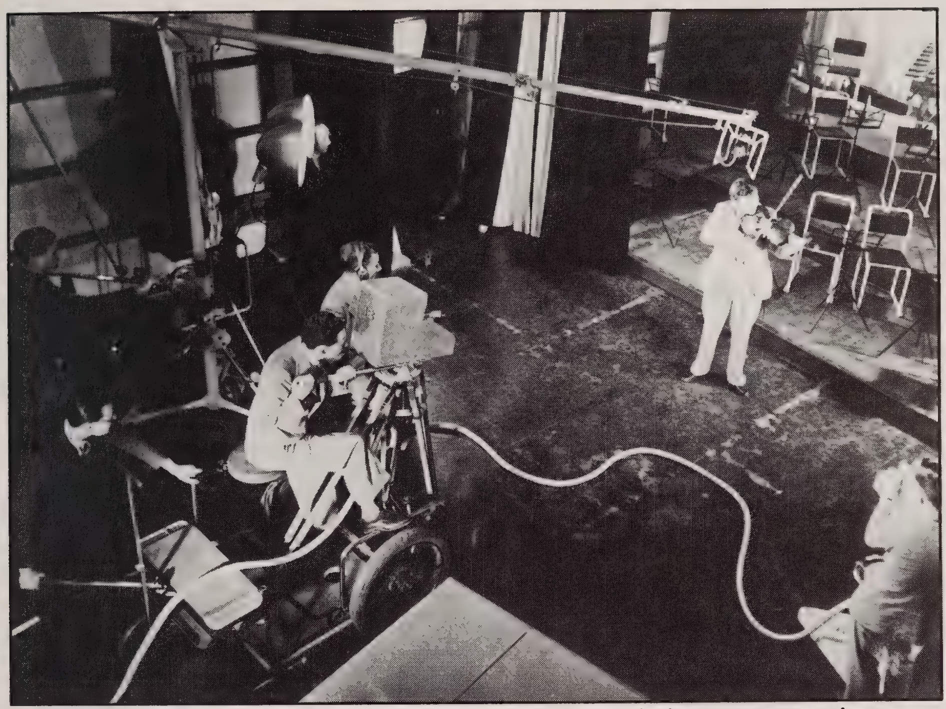
The second limitation of Baird's system lay in the lack of charge storage. Neither his "spotlight" (flying-spot) camera nor the Image Dissector embodied storage mechanisms, the output signal arising only from the momentary exposure as the scanning aperture passed over each element of the scene. The flying-spot camera was therefore very insensitive. The Image Dissector employed electron multiplication and was about ten times more sensitive as a result; but both types of camera required uncomfortably high lighting levels in the studio to produce tolerably noise-free pictures.

To overcome this basic lack of sensitivity Baird devised the intermediate-film system, in which of course the emulsion surface is continuously exposed during the frame period and signal storage does therefore come into play. This did indeed offer reasonable sensitivity, but its immobility, bulk and high running cost were very evident disadvantages.

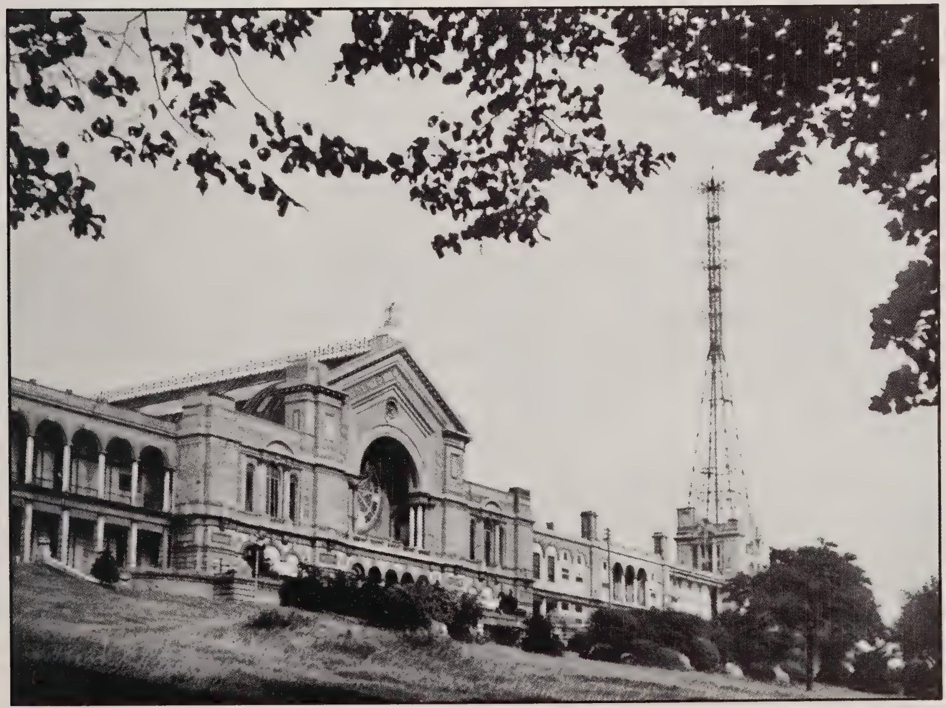
In contrast to Baird, EMI were working from 1931 on electronic television. Isaac Shoenberg, previously with Marconi's and the Columbia Graphophone Company, set up a team at Hayes, Middlesex; including such figures as Blumlein, McGee, Lubszynski and Broadway; and in retrospect it seems inevitable that such an outstanding group should have achieved really notable success. Starting with transmission of films on 120 lines in 1932, EMI were ready by 1935 to match the 240 lines which represented the peak of the Baird system's development. But Shoenberg's team were not content to simply match their rival, and out of the blue they offered the Television Advisory Committee a remarkable leap to a 405-line/50-fields-per-second standard. This bold and imaginative decision by Shoenberg, triumphantly justified by the subsequent service which was finally closed only in 1984, set standards for television throughout the world in terms of picture definition and waveform techniques.

The success of the Marconi-EMI system depended of course on excellence in all parts of the chain. The camera embodied McGee and Lubszynski's Emitron tube, similar in principle to the Zworykin Iconoscope developed in the United States, with electron-beam scanning of a photosensitive mosaic bringing the benefits of charge storage. The circuitry and waveform specification were largely due to Blumlein, much helped by EMI's access to the RCA interlacing patent. To Broadway goes credit for display cathode ray tube developments. And of course the association with Marconi's made available the necessary experience and skill for the wide-band VHF transmitter and aerial.

After a brief period during which the Baird and Marconi-EMI systems were transmitted in alternate weeks, the British television service was based exclusively on the all-electronic system from February 1937.



Broadcasting from Alexandra Palace, 1936. Two Emitron cameras in use.



Alexandra Palace, 1950

405-LINE TELEVISION: THE FIRST THREE YEARS

The original Emitron cameras were comparatively unsophisticated affairs. For example, they had no viewfinders, although this was soon rectified by provision of an optical viewfinder with a second lens alongside the camera lens. The viewfinder picture was upside down, but nobody seemed to mind too much: at least the display was in colour, which is more than can be said of present-day camera viewfinders!

The Emitron was not a very good tube for telecine work (televising pictures from film) and indeed the quality of film reproduction was about the only aspect in which the Baird apparatus had been superior to the Marconi-EMI system. The spurious shading signals (tilt and bend) of the Emitron proved very difficult to correct in the film scanning application where abrupt changes of scene lighting balance could be expected, and, because the telecine system involved a brief flash exposure during the scanning flyback period, the resulting large Emitron "photo pulse" proved troublesome. This latter difficulty was later removed by replacement of the intermittent-motion projector by a Mechau film transport in which successive tilting mirrors produced a stationary image from continuously moving film. The Emitron could therefore be exposed for the full television field period, avoiding the "photo pulse" and incidentally taking advantage of the tube's charge storage capabilities to reduce the required illumination.

Outside broadcasts were an early feature of the new television service, although at first the cameras could venture only into the grounds of Alexandra Palace to the maximum 1000-ft extent of their cables. Early in 1937 a balanced-pair vision cable link was provided from central London to Alexandra Palace, and it was this that enabled the BBC to mount their first true outside broadcast. This was the Coronation of King George VI in May 1937. It attracted the then-huge audience of some 50,000 people. Soon after this the BBC acquired two mobile 3-camera O. B. vehicles and VHF radio links, enabling flexible coverage of all kinds of sporting and other events.

In those early days television was not regarded as the essential service it has now become. Odd though it seems to us today, the service closed down for three weeks in July 1937 to give the staff a holiday after the strenuous months of getting the service launched.

The period 1936-39 saw considerable development in the techniques and variety of program-making, but not much expansion of facilities apart from the O. B. units already mentioned. A notable technical advance was the introduction in 1937 of the Super Emitron, a camera tube of the image-iconoscope type in which an image section with electron multiplication gave considerably improved sensitivity.

With war inevitable, the service was closed down on September 1st, 1939, the last transmitted words being by chance those of Mickey Mouse, "I tink I go home."

POST-WAR EXPANSION

Towards the end of the war, consideration was given by the Government's Hankey Committee to the standards on which the television service should reopen. It was decided, for the sake of an early start, to retain 405 lines; and so it

was that British television returned in June 1946, the first service in Europe to re-open. Included in the opening program was the same Mickey Mouse cartoon that had ended transmissions in 1939; and on the following day there was major outside broadcast coverage of the Victory Parade.

An urgent post-war task was to spread coverage of television throughout the country. Four new high-power transmitters, all in VHF Band 1, at Sutton Coldfield (Midlands), Holme Moss (Northern England), Kirk O'Shotts (South Scotland) and Wenvoe (South Wales) were completed by 1952, bringing 81% of the population within range. They were followed by five medium-power stations, giving 93.5% coverage by 1955. The original Alexandra Palace transmitter was replaced in 1956 by one of greater power at Crystal Palace in south London. With additional low-power relay stations, final 405-line coverage of 99.5% was achieved by 1970.

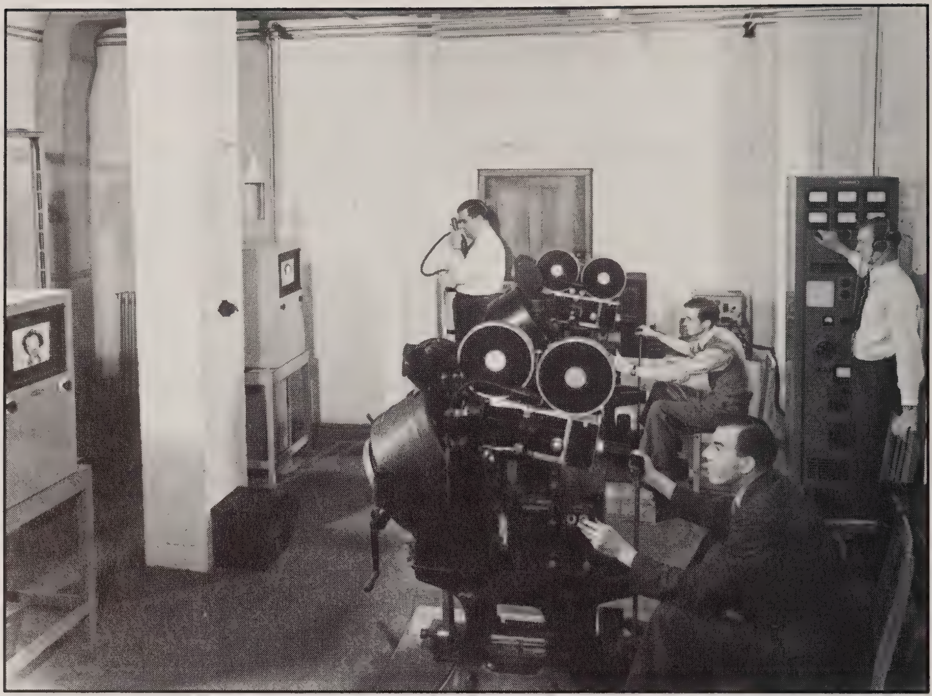
On the program-origination front, it was outside broadcast facilities that first received attention with improved CPS Emitron (orthicon) cameras in 1947; and zoom lenses in 1949, with only a 2:1 range of focal length but still an important advance. More studios were acquired - Lime Grove in 1950, the Shepherds Bush Empire theater in 1953 and the Riverside Studios in Hammersmith in 1956. The White City exhibition site was purchased in 1949 for a future Television Center. A start was made on Regional television studios with a converted chapel in Manchester.

Studio equipment steadily improved, with the old Emitron camera tubes replaced successively by the CPS Emitron, image iconoscopes from EMI and Pye, and the 3" and 4-½" image orthicons. Twin-lens flying spot telecine took over from Emitron tube types in 1949; and special effects systems such as inlay and overlay (equivalent to the cinema's travelling matte) offered new production opportunities.

VIDEO RECORDING

A much needed development in this post-war era was some system for recording television pictures. In sound recording the only feasible approach is to make a replayable representation of the sound signal waveform. The same approach can be taken to video recording, but in this case there is an additional possibility in that a pictorial record of the television display can be made on film.

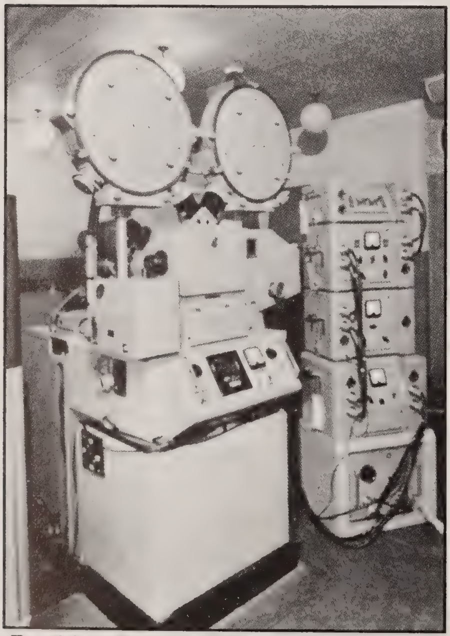
It was the waveform approach that was first adopted when gramophone disc recordings were made of the early 30-line television transmissions, quite practicable since the signal bandwidth was only a little over 10 kHz. But for 405-line television with a bandwidth of 3 MHz, waveform recording was not at first possible and picture recording on film was the only method employed until 1958. The first BBC film recordings were achieved experimentally in 1947 using the simplest possible approach with a conventional intermittent-motion film camera in front of the television screen. The film was run at 25 frames per second and the mechanism synchronized with the 25 pictures per second television display. Since time had to be allowed to pull the film down, only one of the two fields in each television picture period could be recorded. This resulted in a coarse recorded line structure giving rise to beat-pattern problems on replay. A few years later this problem was much reduced by application of "spot wobble" to remove



Film recorders at Alexandra Palace, 1950.

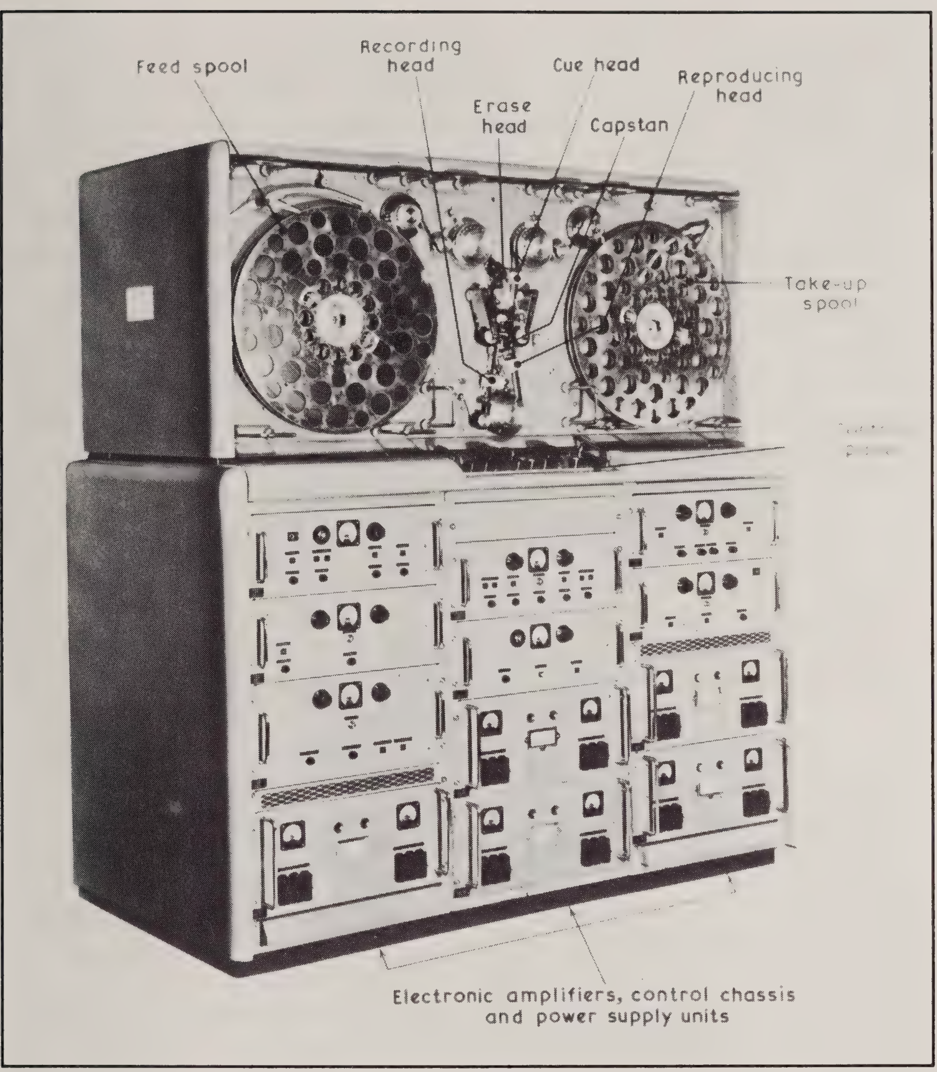
the line structure from the recorder display.

The problem of finding time to pull the film down was resolved in three different ways. Firstly the problem was avoided altogether by using the Mechau continuous-motion transport mechanism with tilting-mirror compensation for film motion. In a second approach the missing television field was stored in the form of afterglow of a long-persistence display tube phosphor, thus presenting both fields simultaneously to the film. A third approach used fast pull-down mechanisms with the aim of completing the film movement during the television field-blanking period: this proved possible with 16-mm film, but 35-mm film could not withstand the required accelerations and about 60 lost lines had to be recovered by display-phosphor storage.



Rapid-pull-down 35-mm Telerecording equipment, 1958.

Having moved from the 1930s waveform recording to picture recording, the pendulum swung back to waveform recording in 1958. Improved magnetic tape materials and techniques made possible the brief appearance of the



Vision Electronic Recording Apparatus, 1958.

BBC's Vision Electronic Recording Apparatus (VERA) in which the video signal was frequency-divided between two longitudinal tracks on ½-inch magnetic tape running at 200 inches/second. Sound was recorded on a third track.

VERA was almost immediately eclipsed by the appearance of Ampex's VR-1000 quadruplex VTR, transverse tracks being laid down on two-inch tape by four rotating heads. The longitudinal tape speed was about 15 inches/second.

Although video recording on film had done yeoman service for ten years, it could not match the quality and operational convenience of the video tape recorder. The VTR revolutionized television production techniques and has continued as a vital tool throughout developments from 2" quadruplex to several new formats.

THE INTRODUCTION OF COLOUR

In principle the generation of colour television signals presents no great prob-

lem and indeed Baird demonstrated such a thing in the 1920s. For a simultaneous colour system (avoiding the movement-portrayal problems of sequential methods) all that is needed is to build three monochrome cameras into one box, add three optical filters and a splitter prism, and the job is done. In practice much ingenious design had been necessary to achieve acceptable results, and the advent of the lead-oxide vidicon (Plumbicon) camera tube and its relatives solved many of the problems of achieving three accurately matched picture signals.

More fundamental innovation was required to devise a compatible colour transmission system, with a luminance signal which existing black-and-white receivers could use without disturbance, and with the additional chrominance information accommodated within the existing channel bandwidth. The solution lay in frequency-division multiplex, with the luminance signal remaining unaltered and two chrominance components modulated in quadrature on a subcarrier within the video band. The third colour component could be derived in the receiver by subtraction of the first two from the luminance signal. Interference between luminance and chrominance components was minimized, on static pictures at least, by choice of sub-carrier frequency to give frequency interleaving of luminance and chrominance signal harmonics.

The first system based on these principles was developed in the USA, largely by RCA, under the auspices of the National Television Systems Committee (NTSC) and received FCC approval for broadcast use in 1953. Later derivatives, PAL and SECAM, largely overcame the susceptibility of NTSC to phase distortions during transmission and reception. The price for this benefit was reduced vertical resolution in coloured areas, but this could be more easily accepted on the 625-line standards used by most countries adopting PAL or SECAM.

On the receiver display side, early equipment was based on the same techniques as were used for picture generation: images from three monochrome picture tubes, each with an appropriate colour filter, were optically superimposed into a composite colour display by means of a mirror system. The later shadow-mask tube used the same principle, consisting in effect of three colour phosphor screens in one glass envelope. No additional optical superimposition is necessary since the human eye cannot resolve the individual red, green and blue elements of the matrix screen. RCA's shadow-mask techni-

VERA in control room with monitor receiver.

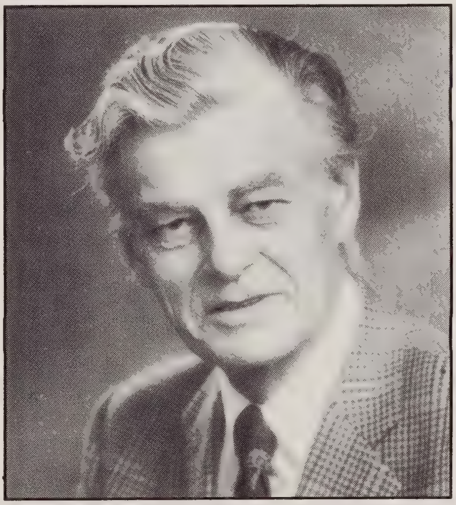
que, whereby each electron beam can stimulate only one set of red, green or blue phosphor elements, deserves much credit as a landmark in the development of domestically practicable colour television.

European opinion was divided on the choice between the French SECAM and the German PAL colour coding systems. While France and some French-influenced countries stuck to SECAM, most European countries, including the UK, adopted PAL. It was decided that British colour television should be on 625 lines only and the BBC2 network commenced colour transmissions in 1967, the first colour service in Europe. BBC1 and Independent Television went into colour at the start of their 625-line services in 1969.

CONCLUSION

This review has taken us to within 20 years of the present day and to go any further would perhaps invalidate the title reference to "early" television. In any case the more recent developments are no doubt sufficiently well known to make further review unnecessary.

Donald Patrick Leggatt, B. Sc., C. Eng., F. I. E. E.



Pat Leggatt was born in Devon on St. Patrick's Day, 1925. His first scientific research project came at the age of nine, when he pushed a thumb into an empty light socket, whereupon he was bitten by the electrical bug which stayed with him throughout his career.

After graduating in physics at Bristol University, he joined EMI Research Laboratories in 1949, where he worked on television camera development, including an experimental 1000-line image iconoscope channel. He joined the BBC in 1953, succeeding to a variety of posts including Engineer in Charge of Telecine & Television recording and Head of Studio Capital Projects Department. He retired in 1987 after a final three years as Chief Engineer External Relations.

Remembering the building of his first wireless set at the age of 14, he joined the British Vintage Wireless Society in 1981, serving as Chairman for three years from 1987. Recent appointment as a District Councillor now leaves him with less free time and he stepped aside as BVWS Chairman in October 1990, although continuing very active involvement in the affairs of the Society.

He is interested chiefly in European and American vintage wireless history of the 1920s and earlier; and in collecting hardware of the period. He is a keen AWA member and his collection includes a fair proportion of American sets. He likes to ensure that virtually everything in his collection can be demonstrated in a working state, including such items as a Marconi Magnetic Detector and a 1902 Lodge-Muirhead mercury coherer.

SIGNAL CORPS SCR-RC-BC DIRECTORY

Frederick W. Chesson
Waterbury, Connecticut

INTRODUCTION

The tables that follow list U. S. Army Signal Corps equipment in three forms: complete systems, as designated SCR (Set, Complete, Radio; later, Signal Corps Radio); subsystems and auxiliaries, termed RC (Radio Component); and individual assemblies, termed BC (Basic Component). This system was used from before WW I to the early years of WW II, when the more descriptive Army-Navy (AN) nomenclature came into use. Since the Signal Corps was responsible for electronics in Army aviation, a great deal of avionics equipment is involved along with ground gear.

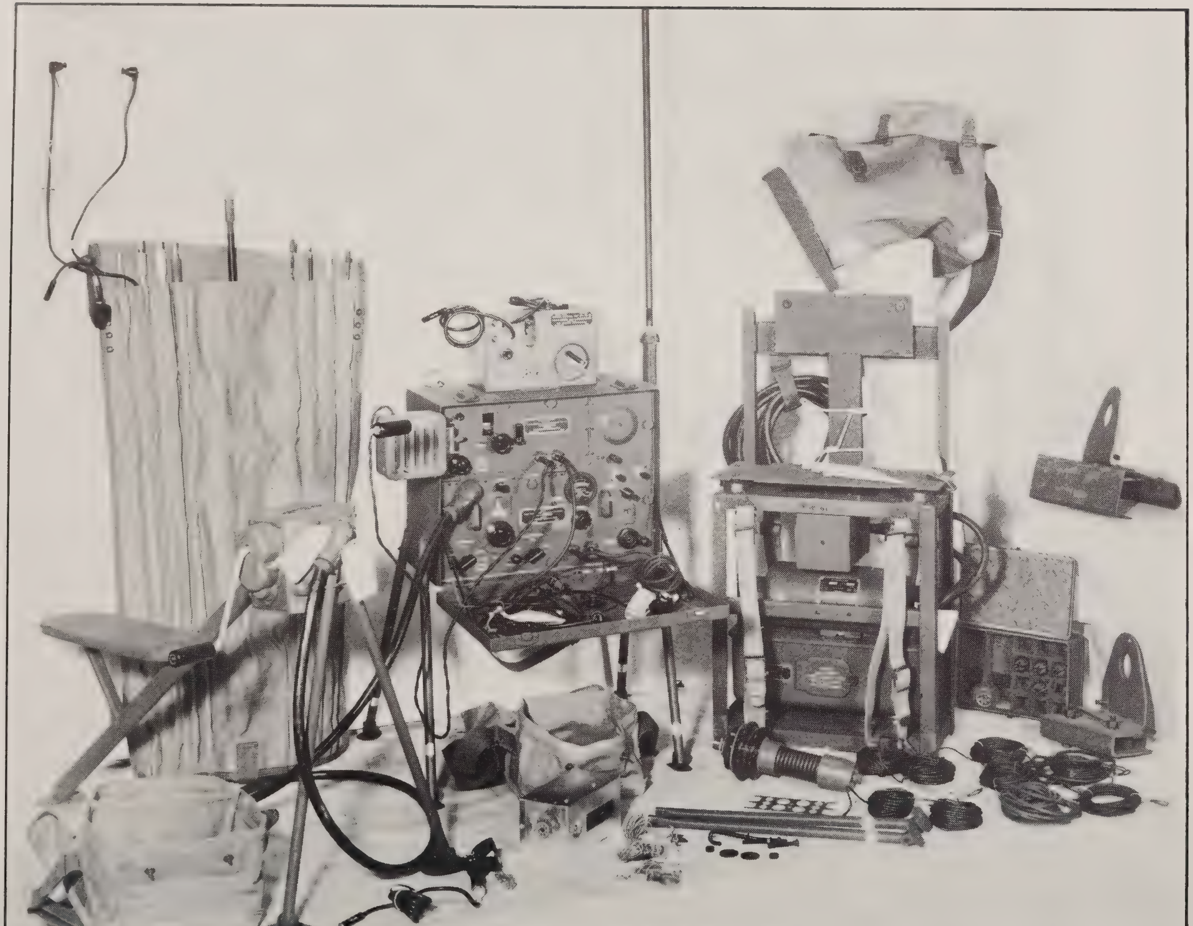
Entries in these listings depict the progress of military electronics technology: from spark communications, to early aircraft radiotelephones, to radio navigation aids, to early radars, to radar countermeasures.

As an example of the importance of electronics in even the early years of WW II, consider a large aircraft like a B-17. Such a craft would typically have a long-range "liaison" radio (SCR-287), a short-range "command set" (SCR-274N), and a crew interphone (RC-36). For navigation, it would carry a radio compass (SCR-279), a radar altimeter (SCR-518), a glide-slope receiver (RC-103), and a marker-beacon receiver (RC-43). To prevent confusion when under radar observation, it would have an identification-friend-or-foe (IFF) transceiver (SCR-515). For emergencies, it would carry a hand-cranked rescue transmitter (SCR-778). As avionics developed further, more systems were added or substituted, depending on specific needs: VHF communications, radars and radar countermeasures, pulse navigators (LORAN, SHORAN, Rebecca, etc.), and so on. Similar rapid evolution occurred in ground equipment, for example the widespread change from high-frequency radio to VHF for mobile tactical purposes.

Because of the extraordinary development effort in the electronic field in WW II, some of the assigned numbers represent items that were not produced, or that were obsoleted before significant use. An example is the SCR-618 radar altimeter, an improved SCR-518 of which only six were made before the replacing SCR-718 was adopted. Other entries indicate upgrades of successful systems. For example, the widely used SCR-270 ground radar began with basic components in the BC-400 series, but continually received redesigned elements in the BC-700, -900, and -1200 series as production continued. - *The Editor*

The author has assembled this material from a variety of sources, many of them fragmentary. Technical manuals (especially the AN 08 and TM 11 series) are cited where possible. Symbols used in the listings are:

*: Several (mostly alphabetic) variations exist.
P/O: Part of
R/B: Replaced by
U/W: Used (in association) with
"Radio" or "radio set" implies separate receiver and transmitter units.



SCR-284

Field radio, made by the Crosley Corporation. At left: bag with sections (MS-118 et al.) to assemble a 25-foot vertical antenna; also a GN-45A six- and 500-volt hand generator for transmitting in portable use. At center: BC-654A, a seven-tube superheterodyne receiver and six-tube transmitter. Set is rated at outputs of 12 watts AM or 25 watts CW at 3.8 to 5.8 MHz. Atop the BC-654, an RM-29 (RC-290) remote-control unit for push-to-talk operation from a distant field telephone. Below the BC-654A, a PE-104 vibrator supply for the receiver in mobile use. At right: a PE-103A six- or 12-volt dynamotor for the transmitter, and mobile antenna base. At far right: a spare-parts kit. Various accessories: T-17 microphones, HS-30 headsets, CW key, mobile antenna mounts, etc.

Photo: AWA Museum

DIRECTORY OF SCR ITEMS

SCR-40	Fixed Station, 3 kW, "developed before 1907, obsolete since 1915"
SCR-41	Field Wireless Wagon, 1-kW quenched spark transmitter, crystal receiver, PE-27 power unit
SCR-42	Radiotelegraph Station, 1 kW, 500-Hz Marconi set for Coast Artillery
SCR-43	Fixed Station: receiver, 10-kW transmitter, quenched gap and 26 Leyden-jar capacitors, 20-HP generator, two 200-foot towers
SCR-44	Field Wireless Set, R/B SCR-49
SCR-45	Receiver, with Cohen crystal detector, National Electrical Supply Co.
SCR-46	Receiver, "Cohen Static-Coupled Receiving Set"
SCR-47	Field Radio ("wagon set"), in artillery caisson, 2 kW, range 75-800 miles
SCR-48	Radiotelegraph, table-top, ¼ kW, like SCR-49 but with M-G set, for coast defense
SCR-49	Pack Set (BC-24), crystal receiver, 0.125-1.0 MHz, ¼-kW quenched gap transmitter, 0.73-1.0 MHz, GN-8 hand generator
SCR-50	Radio on truck, 2-kW spark xmtr, xtal or VT rcvr, 0.15-0.50 MHz
SCR-51	Aircraft Transmitter, 500-W quenched-gap and 500-Hz wind gen.
SCR-52	Aircraft Receiver, regenerative detector and one audio stage.
SCR-53	V-antenna for training, receiving & transmitting
SCR-54, 54A	Receiver, Artillery-spotter (BC-14) (AR-4)
SCR-55	Detector, One-tube (BC-19/DT-3) for SCR-54
SCR-56	Aircraft Training Transmitter, low-power, R/B SCR-65
SCR-57, 57A	First Aircraft Intercom (BC-10), for pilot and observer-gunner
SCR-58	Transmitter, sending unit of SCR-68.
SCR-59, 59A	Receiver (BC-12), receiving unit of SCR-68, U/W SCR-65 xmtr
SCR-60	Wavemeters, General Radio Co., total coverage ca. 0.15-6.0 MHz with A, B, C versions
SCR-61	Wavemeter (BC-37), Western Electric Co. lab unit, 0.125-2.0 MHz
SCR-62	Observation-Balloon Radio (SCR-54 receiver plus SCR-73 xmtr)
SCR-63	Transmitter, Aircraft Radiotelegraph
SCR-64	Aircraft Transmitter, rotary gap powered by wind generator
SCR-65, 65A	Aircraft Transmitter (BC-15, 15A), with quenched gap
SCR-66	Battery-Charging Set
SCR-67, 67A	Ground Radiophone (BC-13A), rcvr 500-1500, xmtr 0.67-1.2 MHz
SCR-68, 68A	Aircraft Radiophone (BC-11), rcvr 500-1600, xmtr 0.67-1.5 MHz
SCR-69	Aircraft CW Transmitter (BC-34), 0.20-0.50 MHz (one VT-12; first SigC VT transmitter)
SCR-70	Receiver (BC-23), one-tube regenerative, 0.20-0.50 MHz
SCR-71	Ground-Return Telegraph Set (BC-16), French TPS (*telegraphie par sol*) type, for trench use
SCR-72, 72B	Ground Telegraph Set (BC-17), SCR-71 with VT amp in receiver
SCR-73	Aircraft CW Transmitter (SCR-64 modified for 0.545-1.50 MHz)
SCR-74, 74A	Ground Transmitter (BC-18, 18A), untuned inductance
SCR-75	Aircraft Receiver-Interphone (BC-10, -20), 0.355-2.0 MHz

SCR-76, 76A	Ground Telegraph (BC-21, 21A), combining SCR-71 and -72
SCR-77	Radio Set, CW "short wave" (BC-38), VT-1 tubes
SCR-78*	Tank Radiotelegraph Set (BC-39 and -40), 0.273-0.60 MHz
SCR-79	Radiotelegraph Set (BC-32), 0.273-0.60 MHz, 4 tubes
SCR-79A	Similar to SCR-79 (BC-32 and -40), three VT-1 tubes, one VT-2
SCR-80	Aircraft Radiotelegraph Set (BC-52), 0.40-0.55 MHz; three VT-1, one VT-4
SCR-81	Triode Tube Tester (BC-41A); tests VT-1 as modulated RF osc.
SCR-82	Battery Charger, 25 & 115 V, 2 kW M-G set, Dyneto Electric Co.
SCR-82B	SCR-82 modified for 50 V, 2 kW
SCR-83	Direction Finder (BC-42), 0.375-1.0 MHz, 6-ft folding loop ant.
SCR-84	Radio Compass, for Handley-Page aircraft
SCR-85	Radiotelegraph Set
SCR-86	Aircraft Radio Maintenance Set
SCR-87	Decremeter, to measure bandwidth of spark transmitters
SCR-89	Aircraft Interphone
SCR-88	Mobile Radio-repair Set
SCR-89	Interphone Set
SCR-90	Aircraft Radiotelephone
SCR-91	Aircraft Radiotelephone
SCR-92	Aircraft Transmitter
SCR-93	Aircraft Radiotelephone
SCR-94	Transmitting-Tube Tester
SCR-95	Wavemeter (BC-40)
SCR-96	Radiotelegraph Set
SCR-97	Truck Radio (SE-1420 receiver, 0.038-1.5 MHz; transmitter 0.1-0.3 MHz), six pliotrons
SCR-98	Receiver
SCR-99	Radiotelegraph Set (BC-45, -49), 0.16-0.33 MHz
SCR-100	Aircraft Transmitter (SCR-64 powered by M-G) (too late for WW I)
SCR-101	Radiotelegraph
SCR-102	Radiotelegraph
SCR-103	Radiotelegraph
SCR-104	Aircraft Interphone
SCR-105	Radiotelegraph Set (BC-53)
SCR-107	Ground Telegraph
SCR-108	Radio Set, truck-mounted
SCR-109	Ground Radiotelephone, like SCR-67, limited production
SCR-110*	Battery Charger, 50 V, 1.5 kW; M-G set from J. L. Yarian Co.
SCR-111	Wavemeter
SCR-112	Radio Set (BC-47), 500-Hz spark transmitter; loop antenna
SCR-113	Aircraft Transmitter (SCR-64 powered by M-G) (too late for WW I)
SCR-114	Aircraft Radio (BC-114), like SCR-68 but less interphone
SCR-115	Aircraft Receiver (BC-12), like SCR-59A but less interphone
SCR-116	Aircraft Radio (BC-11A), like SCR-68A but less interphone
SCR-117	Aircraft Receiver
SCR-118	RF Wire Telegraph Set, used 18-, 23-, 27-, 43-kHz tones; VT-3
SCR-119	Aircraft Direction-finding Receiver

SCR-120	Battery Charger, 125 V, 5 kW M-G set
SCR-121	Audio Amplifier (BC-44A), two-stage
SCR-121A	Amplifier (BC-69), like -121, with 5-ft loop
SCR-123	Battery-Charging Set
SCR-124	Wavemeter, National Electrical Supply Co.
SCR-125	Wavemeter
SCR-126	Radiotelephone Set, VT-2 and VT-3 tubes
SCR-127*	Radiotelegraph Pack Set RE-21 (BC-7), 4 VT-2 & 4 VT-3 tubes
SCR-128	Wavemeter
SCR-129	Aircraft Radio Compass, like SCR-84, 0.285-0.30 MHz
SCR-130	Pack Radio Set, like SCR-127
SCR-131	Field Receiver-Transmitter (BC-148), 4-4.36 MHz (orig. 0.545-1.75), powered by dry batteries and GN-35 hand generator; LP-7 loop antenna for sending and receiving; TM 11-237
SCR-132	Radio Set, CW-AM, receive 0.25-0.545 MHz, send 0.16-0.355 MHz; TM 11-233
SCR-133	Radio, Plane-to-Plane (BC-129), receive 0.25-1.75 MHz, send 0.86-2.0 MHz; ca. 1925
SCR-134	Scout & Bomber Radio (BC-114), CW-AM, receive 0.25-2.0 MHz, send 0.25-0.355 MHz; TM 11-201
SCR-135	Scout & Bomber Radio (BC-114), variant of SCR-134
SCR-136	Radio Set, CW-AM, for artillery fire control; also used with SCR-134; receive 0.25-1.75 MHz, send 0.33-0.86 MHz; TM 11-230, 1926
SCR-137	Wavemeter
SCR-138	Wavemeter
SCR-140	Transmitter, medium frequency, high power
SCR-144	Amplifier
SCR-145	Amplifier
SCR-146	Heterodyne Set
SCR-147	Amplifier
SCR-148	Amplifier
SCR-149	Amplifier
SCR-151	Radio Set
SCR-152	Radio Set
SCR-153	Radio Set
SCR-154	Radio Set
SCR-155	Aircraft Interphone, ca. 1925
SCR-158	Interphone Set
SCR-159	Radio Set
SCR-160	Aircraft Interphone, U/W SCR-134, ca. 1925
SCR-161	Field Receiver-transmitter (BC-151) for artillery nets, 4.37-5.1 MHz version of SCR-131; TM 11-237
SCR-162	Radio Set, for coast artillery, ship and shore
SCR-163A	Radio, for tank & cavalry use, 2.3-2.7 MHz, PE-40 power unit; TM 11-236, 1940
SCR-167	Interphone Set
SCR-168	Interphone Set
SCR-169	Battery Charger PE-HH-43; TM 11-302, 1945

SCR-170	DF Receiver, 1.7-3.3 MHz regen, five 864s, U/W BC-164
SCR-171	Field Radio Set (BC-156), 2-3 MHz; powered like SCR-131 but used wire antenna and counterpoise; TM 11-234
SCR-172	Radio Set
SCR-173	DF receiver (BC-164), used three tuners
SCR-174	Radio Set
SCR-175	Radio Set
SCR-176	Radio Set
SCR-177A	Transmitter BC-191, 75 W, 0.4-1.0 & 1.5-4.5 MHz; BC-189 receiver. Also see RC-47.
SCR-177B*	Same transmitter, but with BC-312 & -314 rcvrs; TM 11-232, 1941
SCR-178	Field Radio Set (BC-186 receiver, BC-187 transmitter, BC-188 screen modulator), 2.4-3.7 MHz, powered by dry batteries and LV-HV generator; TM 11-231
SCR-179	Cavalry saddle version of SCR-178 (same BCs); TM 11-231
SCR-180	Radio Set, BC-189 receiver
SCR-*-183	Aircraft Radio, 14-V command set, (BC-192, -199, -229, -230); receive 0.2-0.4 and 2.5-7.7 MHz; send 2.5-7.7 MHz, 3.5 W CW, designed by Aircraft Radio Corp. and made by WE Co., Stromberg-Carlson, and Philco; TM 11-200, 1932. (SCR-AS-183 is in AN 08-10-158, 1943.) Also see SCR-283.
SCR-*-185	Radio Set, 1-12 MHz (BC-191, -219)
SCR-*-186	Radio Compass Unit
SCR-*-187	Aircraft Radio, 14-V liaison set (BC-224 receiver, 1.5-18 MHz; BC-191 transmitter, 1-12 MHz CW, 75 W)
SCR-*-188	Ground Base (BC-191 transmitter, 1-12 MHz; BC-189 receiver); TM 11-233, 1942. Also see RC-47.
SCR-188A	SCR-188, but with BC-312, -314 rcvrs & RC-47 remote control
SCR-189	Radio Set; TM 11-270, 1940
SCR-190	Radio Set; TM 11-270, 1940
SCR-192	Transmitter (BC-192); TM 11-200, 1932
SCR-193*	Vehicular Transmitter-Receiver, 12-V (BC-191 and BC-189 or -312, 15' whip); TM 11-273, 1941. Also see RC-47.
SCR-194	Radio Set (BC-222), 27-65 MHz, first "walkie-talkie," TM 11-238. Also see RC-63.
SCR-195	Radio Set (BC-322), 53-66 MHz version of SCR-194.
SCR-196	Frequency Meter
SCR-197*	Mobile HF Station (BC-325 transmitter, 1.5-18 MHz, 400 W; receivers: three BC-342, one Hallicrafters "Sky Champion," one BC-325; BC-119 control box; in truck-trailer combination; 45' vertical for sending, 15' whip for receiving; R/B SCR-399; TM 11-241, -805. Also see RC-47.
SCR-199	Radio Set
SCR-200	Radio Set, receiver 1.5-18 MHz, transmitter 2.2-2.6 MHz
SCR-202	Radio Set
SCR-203	Radio Set, mule-pack, 2.1-3.1 MHz CW-MCW-AM, 7.5 W; TM 11-239, 1941. R/B SCR-245.
SCR-204	Pack Radio Set, receive 2.1-3.1 MHz, send 2.2-3.06 MHz

SCR-206*	Receiver, portable, transmitter-locator, 0.2-18 MHz; TM 11-240
SCR-209*	Armored-Vehicle Radio (BC-189 or -312 receiver, 1.5-18 MHz; transmitter 2.2-2.6 MHz, 8 W, 15' whip); R/B SCR-508, -528
SCR-210*	Vehicular Receiver (BC-189 or -312 and 15' whip; TM 11-72, 1942
SCR-211*	Frequency Meter (BC-221-*); TM 11-300, 1943
SCR-213	Radio Set
SCR-233	Radio Set, air-ground liaison
SCR-237	Transmitter, ten-crystal channel version of SCR-188
SCR-238	Radio Set (BC-307 transmitter, BC-224 receiver)
SCR-240	Aircraft Radio, command set, Westinghouse (BC-225, -338); apparently not made in quantity; R/B SCR-274N
SCR-241*	Instrument Landing Navigational Aid (BC-302, -303 and -902); AN 08-10-142, 1943
SCR-242*	Radio-Compass Receiver (BC-310), LF-MF, 14 V; AN 08-10-27, 1940
SCR-243	Receiver, Monitoring (BC-197), 0.10-20 MHz
SCR-244*	Receiver, like -243 (BC-779, -794, or -1004); TM 11-866
SCR-245*	Mobile Radio (BC-223 transmitter, BC-312 receiver, PE-125 vibrapack, 15' whip); R/B SCR-508, -528; TM 11-272, 1942
SCR-246	Radio-Compass Receiver, DF, LF, 12 V
SCR-248	Radio Set
SCR-249	Radio Set
SCR-250	Radio Set
SCR-251	Blind-landing navigational system
SCR-253	Radio Set
SCR-254	Radio Set
SCR-255	DF receiver (BC-903, -904); TM 11-861
SCR-257	Radio Set
SCR-258	Receiver, Radiosonde. See SCR-658.
SCR-259	Aircraft Liaison Radio (brief usage)
SCR-260*	Radio Set (BC-348 receiver, BC-349 transmitter)
SCR-261*	28-V version of SCR-240 (BC-352 receiver, BC-353 transmitter)
SCR-262	Radio Set
SCR-263	Aircraft Radio Compass (BC-463)
SCR-264	Aircraft Radio, 100-130 MHz (VHF version of SCR-274N), R/B SCR-522
SCR-268*	Radar, first Army set, 205-MHz searchlight director (BC-406, -407, -409, -412, -423, -435 to -438, -670 to 672, -968, -1068, -1070, -1161); tested with RC-68; TM 11-1306, -1506. Also see RC-148.
SCR-269*	Aircraft Radio Compass, 12-V, 0.20-1.75 MHz (BC-433 receiver, BC-434 control box, LP-21 antenna, I-81 and I-82 indicators)
SCR-270*	Radar, second Army set, 105-MHz air search, mobile, 100 kW peak (BC-402 to -405, -424, -439, -758 to -760, -780, -785, -968, -986, 988, -1070, -1232, -1239, -1270, -1310; RD-4, RA-60 rectifier, PE-74, -138, -139 power units); TM 11-1510, -1570. Also see RC-148, -150.
SCR-271*	Fixed version of SCR-270, same BC-numbers, used for air defense

	of U. S. coasts; TM 11-1100 (1942), -1310, -1370, -1410, -1510. Also see RC-150.
SCR-272	Radio Set
SCR-273	Radio Compass (BC-413)
SCR-274N	Command Set, famous aircraft set of one to three receivers (BC-453, -454, -455, -942, and/or -946) and up to four transmitters (BC-457, -458, -459, -696, -946, -950, and/or -961), BC-456 modulator, BC-442 antenna relay, control boxes (BC-450, -451, -461, -473, -496, or -938); BC-608 timer, I-155A test set for VHF xmtr; designed by Aircraft Radio Corp. and made by WE Co., Colonial Radio, et al.; based on Navy ARA/ATA system, hence "274N"; predecessor of Navy AN/ARC-5 equipment; AN 08-10-50, 1943. Tested with IE-65, RC-54, and RC-55.
SCR-276	Radio Compass, 28-V version of SCR-246 (BC-383)
SCR-277*	Transmitter, radio-range nav aid, 0.20-0.40 MHz (BC-467, -468)
SCR-278	Radio Set
SCR-279	Radio-Compass Receiver, 14-V version of SCR-269
SCR-280	Radio Compass (BC-431)
SCR-281*	Transmitter-Receiver, for harbor vessels, 1.7-2.25 MHz (BC-441, -619); TM 11-244, 1945
SCR-282*	Radio Compass, 28-V version of SCR-242, AN 08-10-27, 1940
SCR-*-283	Aircraft Radio, 28-V version of SCR-183 (BC-398 control box, -399 or -408 ant. relay, -429 receiver, -430 transmitter); TM 11-200
SCR-284*	Radio Set, Crosley, 3.8-5.8 MHz, 25 W CW, 12 W AM (BC-654, GN-45A hand generator, PE-103 dynamotor, PE-104 vibrapack), R/B SCR-694; TM 11-275. Also see RC-289, -290 and -302.
SCR-285	Radio Set, like SCR-284 (brief use)
SCR-286	Radio Set
SCR-287*	Aircraft Radio (BC-348 and -375), 28-V version of SCR-187
SCR-288	Receiver-Transmitter, RCA, 2.3-6.5 MHz (BC-474, batteries, GN-44A hand generator), R/B SCR-284; TM 11-250, 1942
SCR-289	Radar Set, improved SCR-270, -271
SCR-290	Radio Set
SCR-291	Receiver, DF, 2-10 MHz, with CRT display, made by FTR Co.; TM 11-243, 1950. Also see RC-223.
SCR-292	Receiver (BC-1004); TM 11-866, 1944
SCR-293*	Transmitter-receiver, first FM set for Armor, 20-28 MHz, 25 W (BC-499 and -500), R/B by SCR-508, -528
SCR-294*	Receiver, 20-28 MHz FM, R/B SCR-538
SCR-295	Radio Set
SCR-296	Radar, 700 MHz, third Army radar (BC-716 to -720, 723 to -726)
SCR-297	Navigation Aid, early SHORAN (SHOrt RAnge Navigation), R/B AN/APN-5 and AN/CPN-2, 1943
SCR-298	Mobile FM Radio Set, early, 30-40 MHz, 35 W; based on Link 25-FMTR police-car set; TM 11-609
SCR-299	Mobile HF Station, 2-8 MHz, 350 W, R/B SCR-399 (see -399 for components); TM 11-280
SCR-300	Radio Set, Backpack, Motorola (BC-1000), 40-48 MHz FM,

2 W; TM 11-242, 1945. Also see RC-291, -292, -296, and -300.

SCR-399 Mobile HF Station, 2-20 MHz, 400 W CW, 300 W AM; (two BC-342 receivers, Hallicrafters BC-610 transmitter, BC-614 speech amplifier, BC-939 ant. tuner, BC-1052 multimeter, RA-63 rectifier, in HO-17 shelter on 6 X 6 truck; PE-95, -197 power units in K-52 trailer). Developed into AN/GRC-26 & AN/MRC-2. Also see SCR-299, -499; TM 11-281, 1945. MC-543 provides added equipment for two-kW RTTY operation.

SCR-474 Receiver-Transmitter

SCR-499 Radio Set, shelterless air-transportable version of SCR-399

SCR-500 Radio Set, like SCR-510; TM 11-603

SCR-501 DF Receiver

SCR-502 DF Receiver, 1.5-30 MHz (BC-1147), FTR Co., later AN/CRD-2; TM 11-256, 1945. also see RC-223.

SCR-503 DF Receivers (BC-973, 0.1-3 MHz; BC-1003, 0.1-1 MHz); TM 11-246

SCR-504 DF Receiver 0.1-65 MHz, BC-792 ; TM 11-862, -1460, 1943

SCR-505 Transmitter, 2-20 MHz high-power mobile unit. See SCR-597.

SCR-506 Vehicular Radio, GE, 2-4.5 MHz (BC-652 receiver, -653 transmitter, -658 control box) TM 11-630, -4007, 1944

SCR-508* Vehicular Radio, WE Co., 20-28 MHz FM (two BC-603s, -604, -605); TM 11-600, 1943. Famous "tank radio set," related to SCR-528/538, SCR-608/-628/-638, SCR-708/-728/-738, and SCR-808/-828. Also see RC-163.

SCR-509* Pack radio, 20-28 MHz FM, 1 W (80 xtals) (BC-620); TM 11-605, 1943. Also see SCR-510, -609, 610.

SCR-510* Vehicular Radio, 20-28 MHz FM, 1 W; (BC-620 transceiver, PE-97 power unit, PE-120 vibrapack, AN-45 antenna), for dry batteries, 6 V, or 12 V; TM 11-605, 1943. Also see SCR-509, -609, -610, and RC-163.

SCR-511* Radio Set, portable "guidon" design, Motorola, 2-6 MHz, 0.75 W (BC-745 transceiver, -746 tuning unit, T-39 chest unit, dry batteries); TM 11-245, 1943. Also see RC-303.

SCR-513 Radio Set

SCR-515 Aircraft IFF Set, like Navy ABA and British Mark I, GE, 435-500 MHz (BC-645 transponder, -646 control box, -705 manual destruction switch, -706 automatic self-destruction switch, -727 destruction-warning indicator, PE-101 dynamotor); tested with I-86 test unit); AN 08-5-50, -62, 1942. Also see RC-227.

SCR-516 Radar, later version of SCR-268 for ground controlled interception (few used) (BC-435, -438, -497, -612, -618, -621, -623, -1050); TM 11-1306, -1506, 1944

SCR-517 Radar, early airborne S-band (BC-781, -931, -932, -955, -992, -993, -995, -1101). Also see RC-227.

SCR-518 Aircraft radar altimeter, 515 MHz (BC-688, -689, -690). R/B SCR-618 and -718; AN 08-10-172, 1943

SCR-519 Radar, 10-cm, first high-altitude bombing radar, 1942

SCR-520 Radar, 10-cm, first airborne-intercept (BC-740 to -743, -1040,

	-1041, -1043 to -1045; RC-94). Also see RC-110, -225, and -253.
SCR-521	Radar, 170-196 MHz, based on British ASV Mark II (BC-700 to -704, -961 (AN/TRS-1); related to Navy ASE. Also see RC-227.
SCR-522	Famous VHF aircraft radio, 100-156 MHz AM, four channels, 6 W, 28 V, American version of British TR-1143 made by Bendix and Colonial Radio (BC-624 receiver; -625 transmitter; -602, -1175, 1176 control boxes; -629 and -631 jack boxes; AN-104 antenna; PE-94 power unit; FT-244 rack; CS-80 case). Tested with BC-638 frequency meter, BC-1303 test control box, IE-19 and IE-36 test sets, I-139A test meter, and I-95 field-strength meter. SCR-542 is 14-V version. TM 11-509, 1943
SCR-523	Radar, early 10-cm airborne range finder
SCR-525	Radar, weather-balloon DF
SCR-527	Radar, 200-MHz GCI, U. S. redesign of SCR-588 British system (BC-981 to -983 and -985 to -989, RA-67 rectifier). GE contractor, FTR Co. sub-contractor; TM 11-1119, -1319, -1419, -1519, 1943
SCR-528*	Tank radio, 20-28 MHz, 30 W (BC-603 and -604); TM 11-600. Also see SCR-508.
SCR-529	Radio Set
SCR-530	Radio Set
SCR-531	Radio Set
SCR-532	Radar, air search and IFF, short range
SCR-533	Radar, IFF, 500 MHz, long range (BC-663, -665, -666)
SCR-534	Radio Set
SCR-535	Radar, trailer-mounted search and IFF, based on British Mark IIG (BC-647, -648); 1942
SCR-536*	Transceiver, Motorola et al., 3.5-6 MHz AM, 20 mW (BC-611); R/B AN/PRC-4 & 6. Related to SCR-585; TM 11- 235, 1943
SCR-537	Radar, 3-cm, later AN/APS-4
SCR-538*	Radio, SCR-508 with one receiver (BC-603 to -605); TM 11-600
SCR-539	Radar Indicator, PPI, for use with SCR-270, -271 radars
SCR-540*	Radar, Airborne Interception, based on British AI Mark IV, 200 MHz (P-band). Also see RC-110, 225, -253.
SCR-541	Radar, 10-cm, searchlight director
SCR-542	Aircraft Radio, 14-V version of SCR-522 (same BCs but PE-98 power unit); TM 11-509, 1945
SCR-543*	Transmitter-Receiver, Hallicrafters, (BC-669); TM 11-625, 1944
SCR-545	Radar, combined P- & S-band semi-automatic gun-laying unit (BC-1035, -1053 to -1055, -1057, -1069, 1102); TM 11-1327, -1427, -1527, 1944
SCR-547*	Radar ("Mickey Mouse" from twin-dish antennas) (BC-941, -947, -957, MC-363 range converter, RA-58 power unit), mounted on converted acoustic-locator trailer; TM 11-1109, 1943
SCR-548	Radar, Harbor-Defense, 600-MHz. Related to AN/TPS-1, -2, -3. Also see SCR-648.
SCR-549*	Transmitter, TV, RCA (BC-1211, -1212, -1214), for radio control of glide bombs, later AN/AXT-2, -3; AN 08-10-234. Related to Navy ATJ.

SCR-550*	Receiver, TV, RCA (BC-1213, -1214), for radio control of glide bombs, later AN/AXR-1. Related to Navy ATK; AN 08-10-234
SCR-551*	Receiver, DF (BC-976, -978, -991); TM 11-247, 1944
SCR-552*	Receiver, DF, 100-156 MHz
SCR-553*	Radio Set
SCR-554	Radio Set (BC-1005)
SCR-555	Receiver, DF, 18-65 MHz (BC-1005, RC-93, and PE-1554); TM 11-251, 1944
SCR-556	Receiver, DF, 65-156 MHz (BC-1006); TM 11-255, 1944
SCR-557	Radio Set
SCR-558	DF set, combining SCR-206, -284, -504, -612; TM 11-1158, 1943
SCR-559	Radio Set
SCR-560	Radio Set
SCR-561	Control-Net System for up to 4 interceptor squadrons, P/O SCS-2 (BC-686 and PE-99 generator)
SCR-562	Control-Net System (six BC-640 transmitters, 90' mast, and PE-99 generator), P/O SCS-2
SCR-563	Control-Net System (six BC-639 rcvrs and 90' mast), P/O SCS-2
SCR-564	Control-Net System (two BC-639 receivers), P/O SCS-2
SCR-565	Control-Net System (two BC-639 rcvrs and PE-99), P/O SCS-2
SCR-566	Control-Net System (SCR-522, BC-639, and PE-99), P/O SCS-2
SCR-567	Mobile Forward Relay Station (two BC-639 receivers, two BC-640 transmitters, two PE-99 generators)
SCR-570	Receiver, Glide-Path, later AN/ARN-5
SCR-571	Radio Set, with PE-99 generator
SCR-572	Control-Net System (BC-686), P/O SCS-3; AN-08-10-40
SCR-573	Control-Net System, 100-156 MHz AM, 50 W (two BC-640 transmitters, PE-99 generator), P/O SCS-3
SCR-574*	Control-Net System (two BC-639 receivers, BC-685, -686, PE-99), P/O SCS-3
SCR-575	Mobile Forward DF Station (SCR-522, BC-639, PE-99) (AN/TRD-9), P/O SCS-3
SCR-578	Transmitter, "Gibson Girl" life-raft type, 500 kHz CW-MCW, (BC-778 transmitter plus antenna kite and balloons), R/B AN/CRT-3A; AN 08-10-94, 1943
SCR-579	Radio Set
SCR-580	Aircraft Radar, 10-cm, gun director for night fighters, became AN/APG-1
SCR-581	Radar Set
SCR-582	Radar, 10-cm harbor-defense (BC-912, -922, -926, -952 to -956); TM 11-1212, -1312, -1412, -1512, 1944
SCR-583	Radio Set, 2-3 MHz, replaced SCR-203. Pack, vehicular and ground use on 2.2-4.6 MHz, 40 W; TM 11-623, 1944
SCR-584	Radar, famous air-defense and (later) fighter-direction, GE, 10-cm (BC-984, 1056, -1058, -1059, -1062, -1074 to-1076, -1078, -1080, -1085, -1086, -1088 to -1090, -1092 to -1094, -1096, -1130 to -1133, 1397, 1401, MP-61 antenna pedestal, RA-71 rectifier); TM 11-1324, 1946; TM 11-1424, -1524. Related to Navy/Mar-

	ines SP-1M. Also see SCR-784 and RC-148.
SCR-584*	SCR-584 with MC-607A upgrade kit; TM 11-1363, 1563, 1950
SCR-585	Radio Set, range one mile, related to SCR-536 (BC-721 handie-talkie); AN 08-10-106, 1943
SCR-586	Receiver-Transmitter, for radio control of target ships
SCR-587	Receiver, first radar-countermeasures search, 38-3300 MHz (BC-977); related to AN/APR-4 and Navy RBD; AN 08-10-137, 1943
SCR-588	Radar, Canadian-built copy of British long-wave CHL/GCI system (Type 7 height finder) (BC-1105, -1121 to -1129); TM 11-1129, 1944
SCR-588-T1	Radar, trainer version of SCR-588 (BC-1111, -1112); TM 11-1158, -1329, 1429, -1529
SCR-589	Frequency Meter
SCR-590	Radio Set
SCR-592	Glide-Path Transmitter, 330 MHz, later AN/CRN-2
SCR-593*	Receiver, Warning-Network (BC-728), four channels, 2-6 MHz, powered by 2-V battery; TM 11-859, 1943
SCR-594	Radio Set
SCR-595*	IFF Set, MK III, 157-187 MHz (I-band); AN 08-18-033, 1943
SCR-596	Radar Jammer, included AN/ARQ-15
SCR-597	Transmitter, 2-20 MHz, mobile high-power unit (BC-1113 to -1135, -1139), R/B SCR-299
SCR-598	Radar, 3-cm, coastal defense, with PPI display (later AN/MPG-1)
SCR-599	IFF Set, portable (later AN/PPN-10, -11)
SCR-600	Radio Set
SCR-601	Radio Beacon, 100-156 MHz, later AN/MRN-2
SCR-602*	Radar, portable, 212-MHz, copy of British LW (BC-1081 to -1084, -1284). Also see RC-192.
SCR-603	Radio Set
SCR-605	Radio Set
SCR-606*	Charging Set, for BB-51, -52 mini-batteries; TM 11-305, 1944
SCR-607	Receiver, VHF Panoramic, 28-143 MHz (BC-787, -1032); TM 11-867
SCR-608*	Radio Set, Vehicular, 27-39 MHz FM (two BC-683s, -684, -605). SCR-608, -628 and -638 were Field Artillery versions of the SCR-508/-528/-538 "tank radio" series. TM 11-620, 1944. Also see SCR-808, RC-163, and RC-292.
SCR-609	Radio, portable, Field Artillery version of SCR-509, 27-39 MHz FM (BC-659 and dry batteries); TM 11-615, 1943. Also see RC-63.
SCR-610*	Radio, pack or vehicular, Field Artillery version of SCR-510, 27-39 MHz (BC-659 plus vibrapack); TM 11-615. Also see RC-163.
SCR-611	Radio Set
SCR-612	Receiver, Monitoring
SCR-613	Receiver, Monitoring
SCR-614	Receiver, Monitoring, 0.015-0.15 MHz (BC-969 and RA-61A)
SCR-615A	Radar, Ground-Controlled Intercept, 10-cm, 500 kW, fixed U. S. version of British CMH height finder, range to 90 mi., for ground-controlled interception (BC-1241 to -1252, -1279, -1365, RC-248 antenna); TM 11-1341, -1441, -1541, 1944

SCR-616	Receiver, Monitoring (BC-1269 and -1284); TM 11-260, 1945
SCR-617	Radar, airborne search
SCR-618	Radar Altimeter, improved SCR-518. Not produced in quantity; R/B SCR-718
SCR-619	Radio, Vehicular, 27-39 MHz FM (BC-1335 transceiver), later AN/GRC-12; TM 11-619, 1944
SCR-620	Radar Beacon, responding to SCR-520 10-cm radar, later AN/CPN-3
SCR-621	Radar Beacon, responding to SCR-521 170-196 MHz radar (BC-1064, -1098)
SCR-622	Receiver, LORAN (LOng RAnge Navigation), later AN/APN-4, -9
SCR-623	Radio Set
SCR-624	Radio, 100-156 MHz, ground-based SCR-522 (BC-624, -625, -1171, -1314); AN 08-10-185
SCR-625*	Mine Detector (BC-1141); TM 11-1122, -1416, -4016, 1943
SCR-627	Radar (BC-981, -982, -985 to -989, -1227, AN-137, RA-67, -107, PE-138, -139)
SCR-628	Vehicular Radio Set, 27-39 MHz FM, single-receiver version of SCR-608; TM 11-620, 1944. Also see RC-292.
SCR-629	Radio Beacon, 100-156 MHz
SCR-630	Radio Set
SCR-632	Control-Net System (BC-640 transmitters, PE-99), P/O SCS-2
SCR-633	Control-Net System (BC-639 receivers), P/O SCS-2
SCR-634	Direction-Finding Station (BC-639 receiver, PE-214)
SCR-636	Radar Set, 212 MHz, similiar to SCR-588 (BC-1105, -1139, -1186, -1188); TM 11-1342, -1442, -1542, 1944
SCR-637	Forward Relay Station (two BC-639s, two -640s, two PE-99s)
SCR-638	Receiver and Intercom, 20-28 MHz FM (BC-683, -605)
SCR-639	Receiver, DF, later version of SCR-269, also AN/ARN-7
SCR-640	Radar Beacon, responding to SCR-521 radar (BC-1098)
SCR-641	Radio Set, Ground, 50 W, 100-156 MHz (BC-797, -1271, RC-25, RM-31); TM 11-650, 1944
SCR-642	Control-Net System (BC-686, PE-99), for two squadrons
SCR-643	Control Net System (2 BC-640 transmitters, PE-99), P/O SCS-3
SCR-644	Control Net System (2 BC-639 receivers, -686, PE-99), P/O SCS-3
SCR-645	D/F Station (SCR-522, BC-639, -687, PE-100, RA-42, RC-93, -213)
SCR-648	Radar, later version of SCR-548 harbor-defense system
SCR-658	Radiosonde (RAWIN) Receiver, used AN/FMQ-1 recorder, R/B AN/CRD-1; TM 11-1158, 1945
SCR-668	Radar, 10-cm, Sperry searchlight control
SCR-678	Radio Set
SCR-682	Radar, transportable version of SCR-582 (BC-1192, -1194, -1223 to -1225, -1365); TM 11-1261, -1361, -1461, 1561, 1944. Also see RC-182 and -282.
SCR-690	Radio Set
SCR-694	Field Radio Set, 3.8-6 MHz, 20 W CW, 7 W AM , replaced SCR-284 (BC-1306, PE-162 6-V/500-V gas generator or dry batteries, GN-45 or GN-58 hand generator, PE-237 vibrapack).

	Developed into AN/TRC-2 and AN/GRC-9; TM 11-230, -630, -694. Also see RC-302.
SCR-695	IFF Set, Mark III (BC-706, 765, 767, 958, 965, 966); I-Band, 157-187 MHz and G-Band, 200 MHz
SCR-696	Receiver, used with SCR-698
SCR-697	Radio Set
SCR-698	Transmitter, AM-band, 1 kW, for propaganda broadcasting
SCR-700	DF Receiver, 140-600 MHz
SCR-702	Radar, airborne fire-control, 10 cm, like AN/APG-1; developed but never used operationally
SCR-704	Receiver, Intercept
SCR-708	Radio, vehicular, 20-28 MHz FM. "Crystal-saver" version of SCR-508; heavily redesigned internally. Also see SCR-808.
SCR-709	Radio Set
SCR-710	Radio, 20-28 MHz FM, similar to SCR-510 with fewer crystals
SCR-714	Receiver, receiving portion of BC-1306, 3.8-6 MHz
SCR-717	Bombing Radar, 10-cm, used against surfaced submarines etc. (BC-1007, -1091, -1093, -1095, -1142, -1148, -1150 to -1153, -1155, RC-224 or -226). Like Navy ASG. Depending on model, had B- or PPI scope; AN 08-10-173, 1943
SCR-718	Radar Altimeter, 420-450 MHz, 40,000-foot range, 400-Hz (improved SCR-618 (BC-788, I-152 indicator, AT-4/ARN-1 ant.)
SCR-720*	Radar, 10-cm replacement for SCR-520 (BC-1142, -1148, -1149, -1150, -1151). Also see RC-110, -225, -253.
SCR-721	Radio Set
SCR-722	Aircraft Receiver, early LORAN, 400-Hz power (BC-1182); later AN/APN-4, -9; AN 08-10-171, 1943. Used only for training.
SCR-725	Portable radio set, walkie-talkie
SCR-726	AN/APG-5 airborne fire-control radar
SCR-728	Vehicular radio set, 20-28 MHz FM. "Crystal-saver" version of SCR-508
SCR-729*	Aircraft Radar Beacon ("Rebecca") and Air-to-Air IFF Set (BC-800, -929, -1145A, RC-55A); TO 08-10-167, 1943. Similar to AN/APN-2.
SCR-738	Radio Set, vehicular, 20-28 MHz FM. "Crystal saver" version of SCR-538
SCR-768	Ground Radar, searchlight control
SCR-784	Radar set, 10-cm, trailer-mounted amphibious-landing version of SCR-584 (BC-984, -1071, -1373, -1374, -1398); TM 11-1354, -1454, -1554, 1945. Also see RC-384.
SCR-802	Radio Set
SCR-808	Radio, Vehicular, 27-39 MHz FM, last version of SCR-508 (BC-605, two BC-923, -924); TM 11-601, 1945
SCR-810	Radio Set
SCR-825	Ground Radar, RAWIN, DF for weather balloons
SCR-828	Radio Set, 27-39 MHz, FM, one-receiver version of SCR-808; TM 11-601, 1945
SCR-838	Radar Set

DIRECTORY OF RC ITEMS

Radio Component items were midway between basic components (BC) and complete systems (SCR). For example, RC-150 was an IFF add-on for the SCR-270 and -271 radars, while RC-34 to -38 were interphone units for aircraft and armored vehicles. They appear as early as 1938, most being issued in 1942-43, but some were still mentioned in TM-11-series manuals in the early 1950s. Antenna Equipment RC-292 remained in use into the 1970s, for extending the range of AN/PRC-25/-77 to 12 miles, and the AN/VRC-12 up to 36 miles, at frequencies of 30 to 76 MHz.

RC-10	Microphone Amplifier
RC-12, A	Oscillator Equipment
RC-13	Radio Equipment
RC-14-T*	Radio Training Equipment
RC-15	Interphone Equipment (BC-212)
RC-16,A	Interphone Equipment
RC-17	Sound Recorder
RC-18*	Recording Equipment
RC-19	Microphone Amplifier (BC-216)
RC-20	Marker-Beacon System (BC-301, -400)
RC-21	Interphone Equipment
RC-23	Intra-Aircraft Communication Equipment
RC-24*	Radio Altimeter, forerunner of AN/ARN-1 and AN/APN-1
RC-25	Monitoring Equipment, P/O SCR-641 (BC-354, -355, -356)
RC-26	Interphone Equipment; TO 08-10-13, 1938
RC-27	Interphone Equipment (BC-212B); TO 08-10-13, 1938
RC-28	Frequency Selector
RC-29	Obstacle Detection (radar?) Equipment
RC-32	Range Filter, 1020-Hz pass or reject, for HS-23 headset
RC-33	Marker Beacon
RC-34	Interphone Equipment (BC-334, -335, -347); AN 08-10-248, 1943
RC-35	Interphone Equipment (BC-327, -334, -347); AN 08-10-248, 1943
RC-36*	Interphone Equipment for aircraft (BC-347, -366); TO 08-10-33
RC-37	Interphone Equipment
RC-38	Interphone for M2A3 light tank (BC-367/-667, -368, -369, -370); TM 11-715, 1942
RC-39*	Marker Beacon Receiver (BC-341); TO 08-10-29, -59, -87, 1942
RC-40	Maintenance Set
RC-41	Interphone Equipment
RC-42	Maintenance Set
RC-43	Marker-Beacon Receiver (BC-357); TO 08-10-29, -87, 1942
RC-44	Interphone Equipment
RC-45	Interphone, for aircraft; TO 08-10-31, 1940
RC-46	Marker Beacon
RC-47*	Remote Control, for SCR-177, -188, -193, -197 (RM-12, -13); TM 11-702, TO 08-10-40, 1943
RC-49	Control Equipment
RC-50	Maintenance Equipment

RC-51	Interphone Equipment (BC-347); AN 08-10-248, 1943
RC-52*	Transmitter, 1.5-7.0 MHz, two crystal channels, 50 W, for air-raid warning service
RC-53	Interphone for M3 tank (BC-367, -378, -379, -422, -448, -449, -678); TM 11-700, 1942
RC-54*	Test Set for SCR-274N receivers, three voltmeters and two ammeters; TO 08-10-50, 1943
RC-55*	Like RC-54, for SCR-274N transmitters
RC-56*	Airborne Target Control Transmitter (BC-463, -1204); TO 08-10-182, 1943
RC-57*	Airborne Target Control Receiver (BC-464)
RC-58*	Tape Facsimile Equipment (BC-908, -918, etc.)
RC-59	Power Supply Inverter
RC-60	Interphone Equipment
RC-61	Interphone for M3 tank (BC-367, -369, -370, -379, -422); TM 11-705, 1942
RC-62	Portable Speech Scrambler, for wire or radio
RC-63	Antenna for SCR-194, -195 and -609 radios, TM 11-2616, 1944
RC-64*	Airborne Target Control Receiver (BC-491, -617); AN 08-10-229
RC-65*	Airborne Target Control Transmitter (BC-493); AN 08-40RC65-2
RC-66	Remote Control Equipment (BC-367)
RC-67	Antenna Equipment
RC-68*	Test Equipment for SCR-268* Radar (BC-671); TM 11-1053, 1944
RC-69	Target Transmitter
RC-70*	Test Equipment
RC-71	Air Raid Warning Equipment
RC-72	Radio Receiving Equipment
RC-73	Interphone Equipment (BC-709); TO 08-10-10,103, 1942
RC-75	Electric Fence Equipment
RC-76	Radio Receiving Equipment
RC-77	Radio Receiving Equipment
RC-78	Radio Receiving Equipment
RC-79	Radio Receiving Equipment
RC-80	Monitoring Equipment
RC-81*	Vertical Dipole Antenna for RC-256 Receiver, 100-156 MHz, 1943
RC-82	Antenna Equipment
RC-83*	Antenna Equipment
RC-84	Radio Set Equipment
RC-85	Antenna Equipment
RC-86	Radio Receiving Equipment
RC-87	Message Pick-up Equipment
RC-88	Message Pick-up Equipment
RC-89	Power Supply Inverter; TO 08-10-115, 1942
RC-90	Installation and Testing Equipment
RC-91	Noise Suppression Equipment
RC-92	Control Equipment
RC-93	Target Transmitter, 17.5-158 MHz (BC-655), P/O SCR-555, -556, -575, -645 DF sets, TM 11-5015, 1943

RC-96	Airborne Transmitter, for fighter-plane tracking, one-ppm "pipsqueak"
RC-97*	Antenna Equipment
RC-98	Radio Equipment
RC-99	Tank Interphone (BC-367/-667, -606, -739); TM 11-702, 1944
RC-100*	IFF Equipment (BC-768, -769, -770); TM 11-1113, 1942
RC-101*	Radio Equipment
RC-102*	Antenna Equipment
RC-103*	ILS Equipment (BC-733, etc.); AN 08-10-104, -187
RC-104	Marker Beacon
RC-105	Radio Equipment
RC-106	Keyer Equipment
RC-107	Transmitting Equipment
RC-108	Oscilloscope
RC-109	Antenna Equipment
RC-110	Training Device, for SCR-520, -540 and -720 radar sets (BC-790)
RC-111*	Training Device, for AN/APS-11 radar (BC-691)
RC-112	Control Equipment
RC-113	Control Equipment
RC-115	Marker Beacon Transmitter, 75 MHz (BC-902)
RC-116	Antenna Equipment
RC-117	Grounding Equipment
RC-118	Receiving and Transmitting Equipment
RC-119	Remote Tuning Equipment
RC-120*	Facsimile Set, transceiver like AN/TXC-1; TM 11-375B, 1944
RC-121	Radio Equipment
RC-122	Grounding Equipment
RC-123	Grounding Equipment
RC-124	Antenna Equipment
RC-125	Test Equipment
RC-126	Radio Equipment
RC-127	IFF Set, 157-187 MHz (BC-1267, -1293; I-221A Indicator, RA-105). See also RC-148 and -184; TM 11-1315, 1944
RC-128	Antenna Equipment
RC-129	Antenna Equipment
RC-130	Operating Equipment
RC-131	Operating Equipment
RC-132	Airborne Magnetometer, for ASW use, became AN/ASQ-1
RC-133	Time Control Eqpt for 16 telephone lines, 1-kHz tone signals
RC-134	Switching Equipment
RC-135	Switching Equipment
RC-137	Microphone Amplifier
RC-138	Radio Equipment
RC-139	Transmitting Equipment; AN 08-10-174, 1943
RC-140	Antenna Equipment
RC-141	Radio Equipment
RC-142	Antenna Equipment
RC-143	Antenna Equipment

RC-144*	Antenna Equipment
RC-145	IFF Set (BC-1067, -1266, -1267, RA-105A, I-221A), U/W SCR-545 radar; TM 11-1431, -1531, 1944
RC-146	Interphone for tanks
RC-147	Antenna Equipment
RC-148*	IFF Set, for SCR-268, -270 and -584 radars; TM 11-1118, 1942
RC-149	Cable Recovery Equipment
RC-150*	IFF Equipment, for SCR-270, -271 radars; TM 11-1317, 1944
RC-151*	IFF Equipment, like RC-148*; TM 11-1317, 1944
RC-152*	Transmission Line Equipment
RC-153*	Antenna Equipment, 1944
RC-154	Antenna Equipment; TM 11-2631, 1944
RC-155	Receiving Equipment
RC-156	Radar Jammer, UHF (BC-1017), same as AN/APT-2, 1944; same function as British Carpet I
RC-157	Radio Equipment
RC-158	Target Control Receiving Equipment
RC-159	Target Control Transmitting Equipment
RC-160	Transmitting Equipment
RC-161	Telephone Equipment
RC-162	Antenna Equipment
RC-163	HF Beacon, for vehicular radios like SCR-508, -510, -608, -610; three-element vertical Yagi antenna for 20-39 MHz; TM 11-2609, 1944
RC-164*	Detecting Equipment
RC-165	Receiving and Transmitting Equipment
RC-166	Radio Equipment
RC-167	Radio Equipment
RC-168	Receiving Equipment
RC-169	Sound Recorder, using plastic disks; TM 11-2569, 1946
RC-170	Radio Equipment
RC-171	Radar Homing Bomb Unit for S-band
RC-172	Radio Equipment
RC-173	Antenna Equipment; TM 11-2618, 1943
RC-174	Radio Equipment
RC-175	Interphone Equipment; AN 08-40RC175-2, 1944
RC-176	Radio Equipment
RC-177	Radio Equipment
RC-178	Radio Equipment
RC-179	Sound and Data Recorder, for intercept use; 11-2542, -2543, 1944
RC-180	Facsimile Equipment
RC-181	Antenna Equipment
RC-182*	IFF Set, U/W SCR-682, 157-187 MHz; TM 11-1221, -1408, 1944
RC-183	Radar Jammer (BC-1237, -1255); AN 08-10-156, 1943
RC-184	IFF Set (BC-1267, -1268); TM 11-1332, -1432, -1532, 1944
RC-185	Glide Bomb Control Receiver
RC-186	Glide Bomb Control Transmitter (BC-1158), 1944
RC-187	Antenna Equipment

RC-188*	IFF Equipment, 157-185 MHz (BC-1267)
RC-189	Receiving Equipment
RC-190	Test Equipment
RC-191	Keyer Equipment
RC-192	IFF Equipment, for SCR-602 radar (BC-800); TM 11-1133, 11-43
RC-193*	Marker Beacon Receiver (BC-1023 or -1033); AN 08-10-194
RC-194	Transmitting Equipment
RC-195	Receiving Equipment
RC-196	Homing Adapter Equipment
RC-197	Antenna Tuning Equipment
RC-198	Filter Equipment, 1944
RC-199	Sound and Data Recorder, for intercept use
RC-200	Telegraphic Equipment
RC-201	Beacon Equipment (BC-1064)
RC-202	Test Equipment
RC-203	Receiving and Transmitting Equipment
RC-204	Receiving Equipment
RC-205*	Operating Equipment
RC-206	Operating Equipment
RC-207	Radio Equipment (IFF?); TM 11-1316, 1944
RC-208	Radio Control Equipment
RC-209	Operating Equipment
RC-210	Filter
RC-211	Antenna Equipment
RC-213	Adcock DF Antenna, P/O SCR-645, 1944
RC-214	Antenna Assembly, 10-cm, for SCR-717
RC-215	Radio Equipment (IFF?); TM 11-1334, 1944
RC-216	Marker-Beacon Transmitter
RC-217	Forerunner of AN/APQ-5 low-altitude bombing radar
RC-218	Installation Equipment
RC-219	Antenna Equipment; TM 11-2630, 1944
RC-221	Transmitter
RC-222	Receiver
RC-223	Antenna Equipment, for DF sets SCR-291, -502; TM 11-1159, 1944
RC-224	Parabolic Antenna, 29" x 18", 3100-3400 MHz, with azimuth and elevation drives, P/O SCR-717
RC-225	Training Device, for SCR-520, -540, and -720 radar sets
RC-226	Antenna Assembly, 10-cm, for SCR-717
RC-227	Training Device, for SCR-515, -517 and -521 radar sets
RC-228	Radio Equipment
RC-229	Receiving Equipment
RC-230	Transmitter
RC-231	Antenna Equipment
RC-232	Radar-Beacon Equipment (BC-1098, -1169)
RC-233	Receiving Equipment
RC-234*	Test Equipment
RC-235	Antenna Equipment
RC-236	Analyzer Equipment

RC-237	Installation Equipment
RC-238	Intercom and Monitoring Equipment
RC-239	Intercom and Monitoring Equipment
RC-240	Facsimile Equipment
RC-241	Antenna Equipment
RC-242	Training Device, for LORAN
RC-243	Cord Assembly
RC-244	Cord Assembly
RC-245	Test Equipment
RC-246	Radio Equipment; TM 11-1350, 1944
RC-247	Installation Equipment
RC-248	Antenna, 10-cm, for SCR-615A Radar
RC-249	Antenna Fairlead Assembly
RC-252	Training Device, for LORAN (BC-1184); AN 08-10-253, 1943
RC-253	Training Device, for SCR-520, -540, and -720 radars
RC-254	Antenna System
RC-255	Radio Control Equipment, 1944
RC-256	Receiver (BC-1420, -1421 & RC-81), internal & remote control; AN-08-10-227, 1943
RC-257*	Transmitter AN/FRT-type, companion to RC-256 with internal & remote control, RC-81; AN-08-10-227, 1943
RC-258*	Receiving Equipment
RC-259*	Transmitting Equipment
RC-261	Remote Control, for SCR-300, -509, -510, -608, -609, -610, -619, -628, and AN/TRC-7 radios (RM-52, -53); TM 11-2632, 1944
RC-262*	Transmission Line Equipment
RC-263	Radio Transmitting Equipment (BC-1100); TM 11-816, 1945
RC-264	Antenna Equipment
RC-265	Training Equipment (BC-1420)
RC-266	Antenna Equipment
RC-267	Training Equipment
RC-269*	Transmission Line Equipment
RC-270	Radar Training Equipment (BC-1317, -1315); 1943
RC-271	Test Equipment
RC-272	Antenna System
RC-273	Interphone Equipment
RC-274*	Transmission Line Equipment
RC-275*	Transmission Line Equipment
RC-276	Transmission Line Equipment
RC-277	Antenna Control Assembly
RC-278	Radio Equipment
RC-279	Transmission Line Equipment
RC-280	Radio Transmitting Equipment
RC-281	Antenna Equipment
RC-282	IFF Set U/W SCR-682 radar, 157-187 MHz; TM 11-1221, -1408
RC-283	Test Equipment (BC-1060)
RC-284	Antenna Equipment
RC-285	Test Equipment

RC-286	Antenna Equipment
RC-287	Antenna Equipment
RC-288	Trigger Indicator
RC-289	Remote Control for SCR-178, -284, -399, -608, -694, etc. radios (RM-39, EE-8 telephone, J-47 key); TM 11-2667, 1945
RC-290	Remote Control, for SCR-178, -284, -608, etc. (RM-29, EE-8 telephone), 1945
RC-291	Ground-plane Antenna, to extend range of SCR-300 walkie-talkie
RC-292	Like RC-291, for SCR-300, -608, -628 radios; TM 11-5020, 1950. Later used with AN/PRC-25/-77 & AN/VRC-12; TM 11-5820-348-*.
RC-293	Antenna Assembly
RC-294	Plotting Equipment
RC-295	Goniometer Drive Unit
RC-296	Ground-Plane Antenna, to extend range of SCR-300 radio
RC-297	Homing Attachment
RC-298	Interphone Extension Kit for tanks, (BC-1362, -1361); TM 11-703
RC-300	DF Accessory, for receiver part of SCR-300 walkie-talkie
RC-301	Fixed Antenna Equipment
RC-302	Beacon Accessory, for SCR-284 and -694 radios for troop guidance
RC-303	DF Accessory, for receiver part of SCR-511 walkie-talkie
RC-304	Antenna Assembly
RC-305	Plotting Equipment
RC-306*	Plotting Equipment
RC-307	Antenna Equipment
RC-308	Plotting Equipment
RC-309	Homing Equipment
RC-310	Plotting Equipment
RC-315	Similar to RC-215
RC-316	Radio Equipment
RC-350	IFF Equipment, 157-187 MHz (BC-1267, -1293); TM 11-1346, 1944
RC-351	Radio Equipment; TM 11-1346
RC-384	Mark III IFF Set, 157-187 MHz (BC-1378), U/W SCR-784 radar; TM 11-1362, -1462, -1562, 1944

DIRECTORY OF BC ITEMS

BC-1	Box
BC-2	Box
BC-3	Box
BC-4	Box
BC-5	Chest, for TE-51 welding equipment (used in both World Wars)
BC-6	Box
BC-7	Radiotelegraph set (R-T), 0.55-1.1 MHz, P/O SCR-127
BC-8	Aircraft Receiver-Amplifier, 0.15-0.5 MHz, 6 tubes
BC-9A	Receiver-Transmitter
BC-10	Aircraft Interphone (for pilot and observer-gunner), P/O SCR-57

BC-10A	BC-10 with sidetone circuit added
BC-11A	Aircraft Radiotelephone, AM, WE Co., P/O SCR-68A
BC-12	Aircraft Receiver, 0.35-2 MHz, VT-1 tubes, P/O SCR-59, -59A
BC-13A	Receiver-Transmitter, P/O SCR-67A
BC-14	Receiver, 0.5-1.5 MHz, xtal set of French design, P/O SCR-54
BC-14A	BC-14 with test buzzer added
BC-15	Aircraft Transmitter, quenched-gap, 1-3 MHz, P/O SCR-65
BC-15A	BC-15 with minor improvements, P/O SCR-65A
BC-16	Trench Telegraph, buzzer at 600-1300 Hz, P/O SCR-71
BC-17	Trench Telegraph, like BC-16, with four VT-1 tubes, P/O SCR-72
BC-18, 18A	Transmitter, 10-V, 100-W spark coil, simple gap, P/O SCR-74, 74A
BC-19	Detector, one-tube, for BC-14 (SCR-54), P/O SCR-55
BC-19A	Detector, similiar to BC-19, P/O DT-3A
BC-20	Aircraft Receiver, 0.35-2 MHz, 3 VT-1 tubes, P/O SCR-75
BC-21	Trench Telegraph, SCR-71 & -72 in one unit, P/O SCR-76
BC-21A	Trench Telegraph, improved BC-21, P/O SCR-76A
BC-23	Receiver, 0.175-0.5 MHz, autodyne type, one VT-1, P/O SCR-70
BC-24	Receiver-transmitter, 250-W quenched gap, P/O SCR-49
BC-25	Box
BC-26	Chest, for carrying radio receiver SCR-54-A
BC-29	Amplifier
BC-30	Case, leather, for dry-battery testing, voltmeter I-3 and ammeter I-4
BC-31	Case, leather, for voltmeters I-4, I-6 and ammeters I-7, I-8, I-9
BC-32, 32A	Receiver-Transmitter, 3-tube rcvr, 1-tube xmtr, P/O SCR-79
BC-33	Box
BC-34	Radio Set Box
BC-35	Chest, for packing type A-6 antenna equipment
BC-36	Receiver (Type D Receiving Box), xtal det, P/O SCR-49
BC-37	Wavemeter, 0.125-2.0 MHz, P/O SCR-61
BC-38	Receiver-Transmitter, "short wave," P/O SCR-77
BC-39	Receiver-Transmitter 3-tube rcvr, 1-tube xmtr, P/O SCR-78, 78A
BC-40	Wavemeter, 0.273-0.60 MHz, P/O SCR-95
BC-41	Tester for VT-1 tubes, RF oscillator, WE Type 5730, P/O RE-10
BC-42	Radio Set Box
BC-43	Chest, for carrying radio set SCR-79
BC-44	Amplifier, two VT-1s
BC-45	Receiver-Transmitter, three Vt-1s, one VT-2
BC-46	Auxiliary Transmitter
BC-47	Radio Set, receives 1.82-3.53 MHz; sends 2.143, 2.440, 2.730
BC-48	Box
BC-49	Wavemeter
BC-50	Wavemeter
BC-51	Case
BC-52	Radio Set Box
BC-53	Receiver-Transmitter, quenched gap and crystal detector
BC-54	Chest
BC-55	Transmitter
BC-56	Aircraft Interphone

BC-57	Testing Buzzer
BC-58	Chest
BC-59	Amplifier
BC-60	Switch Box
BC-61	Box
BC-62	Box
BC-63	Test Equipment
BC-66	Box
BC-68	Test Unit
BC-69	Amplifier, four RF stages and VT-1 detector
BC-70	Wavemeter
BC-71	Telephone Box
BC-72	Battery Box
BC-73	Switch Box
BC-74	Switch Box
BC-75	Tool Chest
BC-76	Chest, for TE-6 general-purpose tool set
BC-77	Tool Chest
BC-78	Control Box
BC-79	Chest, two air tanks for EE-17 Strombos gas-alarm horn
BC-80	Chest, for EE-17 Strombos gas-alarm horn unit
BC-81	Control Box
BC-82	Battery Case, leather, for signal lamp
BC-83	Box
BC-84	Control Box
BC-85	Box
BC-86	Transmitter
BC-87	Box, for TE-26 soldering equipment
BC-88	Tool Chest
BC-89	Tool Chest
BC-90	Chest, for TE-14 carpenter tool
BC-91	Tool Chest
BC-92	Control Box
BC-93	Tool Chest
BC-94	Switch Box
BC-95	Switch Box
BC-96	Switch Box
BC-97	Chest, for EE-34 equipment
BC-98*	Radio Set Box
BC-99	Switch Box
BC-100	Amplifier
BC-101*	Amplifier
BC-102	Box
BC-103	Amplifier
BC-104	Receiver, heterodyne type, 0.10-0.30 MHz
BC-105	Amplifier
BC-107	Receiver-Transmitter
BC-110	Transmitter

BC-114	Aircraft Transmitter, ca. 1925, P/O SCR-114, -135
BC-115	Radio Tuner (receiver)
BC-116	Amplifier
BC-117	Switch Box
BC-118	Amplifier
BC-119	Control Box, for BC-325 xmtr & 3 BC-342 rcvrs, P/O SCR-197, -597
BC-120	Control Box
BC-121	Control Box
BC-122	Transmitter
BC-123	Interphone Control Box
BC-126	Jack Box
BC-127	Transmitter
BC-128	Box
BC-129	Aircraft Transmitter, AM, ca. 1925, P/O SCR-133
BC-130	Control Box
BC-131	Receiver, regenerative, like IP-500
BC-132	Control Box
BC-136	Control Box
BC-137	Receiver
BC-138	Radio Tuner
BC-139	Transmitter
BC-140	Audio Filter
BC-141	Amplifier
BC-142	Control Box
BC-144	Receiver, four VT-5 tubes, Wireless Specialty Apparatus Co.
BC-145	Transmitter
BC-146	Receiver
BC-147	Transmitter
BC-148	Field Radio, portable, 4-4.36 MHz, receiver three 864s, transmitter one 10, P/O SCR-131; sends and receives with LP-7 loop ant.
BC-150	Wavemeter, 0.10-2.0 MHz
BC-151	Field Radio, BC-148 for 4.37-5.1 MHz use, P/O SCR-161
BC-*-152	Receiver
BC-153	Wavemeter
BC-154	Transmitter
BC-*-155	Receiver
BC-156	Field Radio, 2-3 MHz version of BC-148, P/O SCR-171
BC-157	Receiver-Transmitter
BC-158	Receiver
BC-159	Receiver
BC-160	Relay Unit
BC-161	Recorder
BC-*-163	Amplifier
BC-164	Balloon Transmitter, 2.4 MHz, one UV-199, U/W SCR-170, -173
BC-*-167	Receiver
BC-168	Radio Tuner
BC-*-169	Radio Tuner
BC-*-170	Radio Tuner

BC-171	Receiver
BC-*-173	Transmitter
BC-175	Receiver
BC-176*	Transmitter
BC-177	Control Box
BC-178	Receiver-Transmitter, powered by dry batteries (90-V B+)
BC-*-179	Receiver
BC-*-180	Transmitter
BC-181	Control Box
BC-182	Control Box
BC-185	Transmitter
BC-186	Receiver, 2.4-3.7 MHz, two 30s and two 34s, P/O SCR-178, -179
BC-187	Transmitter, 2.4-3.7 MHz, one 10 and one 865, P/O SCR-178, -179
BC-188	Modulator for BC-187, two 30s, P/O SCR-178, -179
BC-189	Receiver, superheterodyne, 0.150-13 MHz, eight tubes, 12 V, P/O SCR-177, -180, -188, -193, -209, -210
BC-191*	Transmitter, 12-V, four 211s and one 10, P/O SCR-177, -185, -187, -188, -193; TM 11-800, 1942, -4017. Used tuning units TU-6, etc. BC-AA-191, 1935 original model, required external units: tuners BC-AA-193, -194, or -204; antenna relay BC-AA-196; and control box BC-AA-192. Also see BC-375.
BC-*-192	Control Box U/W BC-191 transmitter
BC-*-193	Antenna Tuning Unit U/W BC-AA-191 (early model)
BC-*-194	Antenna Tuning Unit U/W BC-AA-191 (early model)
BC-*-196	Antenna Relay Unit, U/W BC-191
BC-*-197	Monitoring Receiver, 0.1-20 MHz, P/O SCR-243
BC-*-198	Antenna Relay, P/O SCR-183
BC-*-199	P/O SCR-183
BC-*-200	Transmitter (BC-AC-200), 3 VT-25, 1 VT-52, P/O SCR-AC-183
BC-*-201	Control Box
BC-*-202	Transmitter Control Box
BC-*-204	Antenna Tuning Unit for BC-AA-191 transmitter (early model)
BC-205*	Loop Tuning Unit
BC-206A	Control Box
BC-207-T2	Transmitter
BC-208	Antenna Relay Unit, for BC-191
BC-*-209	Amplifier
BC-210	Receiver
BC-211*	Frequency Meter, P/O SCR-211
BC-212	Interphone Amplifier, one 39/44 tube, P/O RC-15
BC-212-B	Interphone Amplifier, two 6C5 tubes, P/O RC-27
BC-213	Jack Box for BC-345
BC-214	Control box for BC-189
BC-215	Control Box
BC-216	Microphone Amplifier, 6F7 and 39/44 tubes, P/O RC-19
BC-217-T2	Antenna Tuning Unit
BC-219	Aircraft Receiver-Transmitter, 1-12 MHz, P/O SCR-185, -187
BC-221	Frequency Meter, Heterodyne, 0.125-20 MHz (36+ versions), main

	part of SCR-211
BC-222*	Receiver-Transmitter, first walkie-talkie, 28-52 MHz in two bands, 2 W, one 30 and one 33, superregen receiver, modulated-oscillator transmitter, P/O SCR-194. Also see BC-322.
BC-223*	Transmitter, 2-5.25 MHz, 30 W CW, 10 W AM, 801, P/O SCR-245
BC-224*	Receiver, 14-V version of BC-348, P/O SCR-187, -238; TO 08-10-47
BC-225	Receiver, P/O SCR-240
BC-226*	Control Box
BC-227	Receiver
BC-228	Transmitter
BC-*-229	Aircraft Receiver, 0.2-0.4 & 2.5-7.7 MHz, 14 V, P/O SCR-183. Also see BC-429. Related to Navy RU series.
BC-*-230	Transmitter, 2.5-7.7 MHz, 20 W, 14 V, P/O SCR-183. Also see BC-430. Related to Navy GF series.
BC-*-231	Control Box, for BC-229 receiver, P/O SCR-183
BC-*-232	Control Box, modified BC-202, for BC-230 xmtr, P/O SCR-183
BC-235	Control Box
BC-255	Receiver
BC-270	Transmitter, 300 W
BC-301	Marker Beacon Receiver. one 6F7 tube, P/O RC-20
BC-302	Transmitter, Instrument Landing, U/W BC-303 & -902, P/O SCR-241
BC-303	Transmitter, P/O SCR-241; TO 08-10-96, 1942. See BC-302
BC-304	Interphone Control Box
BC-305	Interphone Control Box
BC-306*	Antenna Loading Unit, 0.15-0.8 MHz, U/W BC-191/375
BC-307*	Transmitter, P/O SCR-238
BC-308*	Control Box
BC-309	Control Box, U/W BC-191/375
BC-310	Radio Compass Receiver (RDF), 0.15-1.5 MHz, 14 V, P/O SCR-242
BC-311	Control Box
BC-312*	Receiver, 1.5-18 MHz, P/O SCR-177, -188A, -193, -197, -210, -245. Many models, 12- and 24-V, with and w/o xtal filter; TM 11-850, 1946. Also see BC-342.
BC-313	Frequency Meter
BC-314*	Receiver, 0.15-1.5 MHz, P/O SCR-177B; TM 11-850
BC-315	Transmitter, 2-18 MHz, 400 W CW-MCW-AM, WE Co.
BC-316	Antenna Tuning Unit
BC-317	Oscillator
BC-318	Switch Box
BC-319	Transmitter, six 837s
BC-320	Receiver
BC-321	Control Box
BC-322	Transceiver, 52-66 MHz (one band), like BC-222, P/O SCR-195
BC-324	Receiver, 14-V version of BC-348
BC-325*	Transmitter, 1.5-18 MHz, 400/100 W, P/O SCR-197; TM-11-805
BC-326	Switch Box
BC-327	Control Box, P/O RC-35 interphone

BC-328	Transmitter, three 837s
BC-329*	Transmitter, 0.19-0.41 MHz AM, 25 W, U/W T-27L; TM-11-817
BC-330	Transmitter, three 837s
BC-331	RF Coupling Unit
BC-332	Antenna Tuning Unit
BC-334	Control Box, P/O radio and interphone sets RC-34 & -35
BC-335	Interphone Box, P/O RC-34
BC-337	Transmitter
BC-338	Transmitter, P/O SCR-240
BC-339*	Transmitter, 4-26.5 MHz AM/FSK, 1 kW, FTR Co.; TM 11-836, 1946. Also used as driver for BC-340.
BC-340*	Amplifier, 4-27 MHz, 10 kW, U/W BC-339, AN/FRA-2, RA-22 rectifier, RU-2 water cooler; TM 11-801, 1950
BC-341*	Beacon Receiver, P/O RC-39A; TO 08-10-89, 1942
BC-342*	Receiver, 1.5-18 MHz, 115-V version of BC-312 using internal RA-20 rectifier, P/O SCR-197, -277, -299, -399, -499, AN/MRC-1, MRQ-2, TRQ-1; developed into R-336/GRC-26
BC-343	Antenna Tuning Unit
BC-344*	Receiver, 0.15-1.5 MHz, 115-V version of BC-314, TM 11-850
BC-345	Control Box
BC-346	Receiver
BC-347*	Interphone Amplifier, one 6F8, P/O RC-34, -35, -36, -51
BC-348*	Air and Ground Receiver, 0.2-0.5 & 1.5-18 MHz, P/O SCR-260, -287, AN/ARR-11, AN/ARC-8. "A" through "R" models; many makers; TM 11-692
BC-349	Transmitter, P/O SCR-260
BC-351	Control Box
BC-352	Receiver, P/O SCR-261
BC-353	Transmitter, P/O SCR-261
BC-354	Compass-Locator Monitor, one 6H6, P/O RC-25
BC-355	Marker-Beacon Monitor, one 6H6, P/O RC-25
BC-356*	Monitor Unit, four tubes, P/O RC-25
BC-357*	Beacon Receiver, 62-80 MHz, 12C8 and 12SQ7 tubes, P/O RC-43
BC-359	Receiver
BC-360	Audio Amplifier
BC-361	Interphone Control Box
BC-362	Interphone Control Box
BC-363	Switch Box
BC-364	Loudspeaker Control Box
BC-365*	Transmitter, 0.155-0.55 MHz, 350 W CW/FSK, FTR Co.; TM 11-828, 1944. Also used as driver for Bunnell six-kW amplifier.
BC-366*	Control Box, P/O RC-36 interphone
BC-367	Interphone Amplifier, 12 V, P/O RC-38, -53, -61, -99; TM 11-702
BC-368	Control Box (commander & radio operator), P/O RC-38
BC-369	Control Box (driver), P/O RC-38 and -61 tank interphones
BC-370	Jack Box (driver & gunner), P/O RC-38 and -61 tank interphones
BC-371	Transmitter
BC-372	Transmitter

BC-373	Receiver, P/O SCR-246 LF DF system
BC-374	Control Box
BC-375*	Transmitter, 0.2-0.5 and 1.5-12.5 MHz, 100 W, P/O SCR-287. 28-V version of BC-375.
BC-376*	Test Oscillator, 5 MHz, U/W BE-67 indicator, P/O IE-76, 1942
BC-377	Interphone Amplifier
BC-378	Jack Box, P/O RC-53 tank interphone; TM 11-700, 1942
BC-379	Jack Box (gunner), P/O RC-53 and -61 tank interphones
BC-382	Frequency Meter
BC-383	Radio Compass Receiver, P/O SCR-276
BC-384	Jack Box
BC-385	Jack Box
BC-386	Control Box
BC-387	Control Box
BC-388	Interphone Amplifier
BC-389	Modulator
BC-390	Selector Unit
BC-391	Test Unit
BC-392	Transmitter
BC-393	Transmitter
BC-394	Receiver
BC-395	Receiver
BC-396	Modulator
BC-397	Control Box
BC-398	Control Box, P/O SCR-283
BC-399	Antenna Relay, P/O SCR-283
BC-400*	Transmitter, P/O RC-20 marker-beacon set; TM 11-2607
BC-401*	Transmitter, 2-18 MHz, 400 W AM-CW, U/W RA-30, RM-11
BC-402*	Keying Unit, P/O SCR-270, 271 radars
BC-403*	Oscilloscope, 5BP1 and 5BP4 CRTs, P/O SCR-270, -271 radars
BC-404*	Receiver, 105 MHz, P/O SCR-270, -271 radars
BC-405*	Transmitter, 105 MHz, P/O SCR-270, 271 radars
BC-406	Receiver, 200-210 MHz, P/O SCR-268 radar
BC-407*	Transmitter, 205 MHz, ring oscillator with eight 100TS tubes, P/O SCR-268 radar
BC-407A	Like BC-407, using 16 100TS tubes for 100-kW peak output
BC-*-408	Antenna Relay, P/O SCR-283
BC-409	Keying Unit, 304TL tubes, P/O SCR-268 radar
BC-410	Radio Compass Unit
BC-411	Control Box
BC-412*	Oscilloscope, 5BP4 CRT, P/O SCR-268 radar
BC-413	Radio Compass Unit, P/O SCR-273
BC-414	Control Box
BC-416	Frequency Control Box
BC-418*	Relay Unit
BC-419	Test Unit
BC-420*	Transmitter
BC-422	Control Box (radio operator), P/O RC-53 and -61; TM 11-700, 1942

BC-423*	Modulator, five tubes, P/O SCR-268; TM-11-2636
BC-424*	Modulator, five tubes, P/O SCR-270, -271 radars
BC-426	Loop Director
BC-427	Radio Compass Unit
BC-428	Control Box
BC-*-429	Receiver, 28-V version of BC-229, P/O SCR-283
BC-*-430	Transmitter, 28-V version of BC-230, P/O SCR-283; TM 11-200
BC-431	Radio Compass Unit, P/O SCR-280
BC-432*	Control Box
BC-433	Receiver, Aircraft Radio Compass, 0.2-1.75 MHz, P/O SCR-269
BC-434*	Control Box, U/W BC-433 receiver
BC-435	Modulator, two 250TLs & eight 304TLs, P/O SCR-268, -516 radars
BC-436	Range Unit, P/O SCR-268 radar
BC-437	Converter, P/O SCR-268 radar
BC-438	Frequency Meter, 190-215 MHz, Link Mfg. Co., P/O SCR-268, -516
BC-439	Frequency Meter, 100-120 MHz, 115 V, P/O SCR-270, -271
BC-440	Control Box
BC-441*	Receiver-Transmitter, Marine, 25 W AM, Hallicrafters, P/O SCR-281; TM 11-244
BC-442*	Antenna Relay, used FT-229 mounting plate, P/O SCR-274N
BC-443	Radio Compass Unit, P/O SCR-263
BC-444	Control Box
BC-445	Transmitter, used RM-45 for remote control
BC-446*	A-N Radio-Range Transmitter, 0.2-0.4 MHz, 100 W
BC-447*	Transmitter, 2-13.4 MHz, 300 W CW/FSK, FTR Co.; TM 11-827, 1944
BC-448	Jack Box (driver & gunner), P/O RC-53 interphone; TM 11-700
BC-449	Control Box (commander), P/O RC-53 tank interphone; TM 11-700
BC-450*	Control Box, for three receivers, P/O SCR-274N
BC-451*	Control Box, for up to four transmitters, P/O SCR-274N
BC-452*	Transmitter, 1.5-7 MHz, 300 W AM, two-channel
BC-453*	Receiver, 0.19-0.55 MHz (like R-23/ARC-5), P/O SCR-274N
BC-454*	Receiver, 3-6 MHz (like R-26/ARC-5), P/O SCR-274N
BC-455*	Receiver, 6-9 MHz (like R-27/ARC-5), P/O SCR-274N
BC-456*	Modulator, screen, using FT-225 shock mount, P/O SCR-274N
BC-457*	Transmitter, 4-5.3 MHz (like T-20/ARC-5), P/O SCR-274N
BC-458*	Transmitter, 5.3-7 MHz (like T-21/ARC-5), P/O SCR-274N
BC-459*	Transmitter, 7-9.1 MHz (like T-22/ARC-5), P/O SCR-274N
BC-460*	Transmitter, 2-18 MHz, 250/200 W, U/W RM-20; TM 11-812. Later models same as Navy TDO.
BC-461	Control Box, for trailing antenna, P/O SCR-274N
BC-462	Control Box, for BC-463, P/O RC-56, AN/TRW-1
BC-463*	Target-Control Transmitter, 67-74 MHz, 20 W, 5 tones, P/O RC-56, AN/TRW-1
BC-464*	Target-Control Receiver, 68-73 MHz, P/O RC-57
BC-465	Antenna Reel Control Box
BC-466*	Control Box
BC-467*	Transmitter, 0.2-0.4 MHz, P/O SCR-277 radio range

BC-468*	Goniometer, for SCR-277A
BC-469*	Antenna Tuning Unit
BC-470*	DF Receiver & Loop Rotator, 0.2-18 MHz, P/O SCR-206
BC-471	Transmitter
BC-472	Modulator
BC-473*	Control Box (one receiver), using FT-235 mount, P/O SCR-274N
BC-474	Receiver-Transmitter, portable, 2.3-6.5 MHz AM-CW, 6V6 final, P/O SCR-288; TM 11-250, -4006
BC-475	Transmitter
BC-476	Recorder
BC-477	Receiver
BC-478	Receiver Control Box
BC-479	Meteorograph Unit
BC-480	Meteorograph Unit
BC-481	Receiver
BC-482	Receiver
BC-483	Receiver
BC-484	Transmitter Control Box
BC-485	Receiver
BC-486	Receiver control Box
BC-487	Transmitter
BC-488	Transmitter Control Box
BC-489	Receiver
BC-490	Transmitter
BC-491	Target Controller, P/O RC-64 Remote Control
BC-492	Receiver
BC-493	Transmitter, P/O RC-65 Remote Control
BC-494	Control Box
BC-495	Test Unit
BC-496	Control Box (two receivers), using FT-240 mount, P/O SCR-274N
BC-497	Range Unit, P/O SCR-516 radar
BC-498	Transmitter
BC-499*	Receiver, 20-28 MHz, FM, P/O SCR-293
BC-500*	Receiver-Transmitter, 20-28 MHz FM, 25 W, P/O SCR-293
BC-601	Receiver & Transmitter
BC-602*	Control Box, Channel Selector, P/O SCR-522
BC-603*	Receiver, 20-28 MHz FM, 12-24 V, P/O SCR-508, -528, -538
BC-604*	Transmitter, 20-28 MHz FM, 30 W, 12-24 V, 1624 final, WE Co. and FTR, P/O SCR-508, -528, -538; TM 11-4034
BC-605*	Interphone Amplifier, P/O SCR-508, -528, -538, -608, -628, -638, -808, -828
BC-606*	Control Box, P/O RC-53 and -99 tank interphones; TM 11-700
BC-607	Remote Control Indicator
BC-608*	Timer, Mechanical, "pseudo-IFF set" British keyer for SCR-274N transmitters
BC-609	Keyer
BC-610*	Transmitter, 2-18 MHz, 400 W CW, 300 W AM, developed from Hallicrafters HT-4, P/O SCR-299, -399, -499; TM 11-813, -826

BC-611*	Transceiver, handie-talkie, 3.5-6 MHz, P/O SCR-536; TM 11-235. Also see BC-721.
BC-612	Modified BC-412 oscilloscope, P/O SCR-516
BC-613	Antenna Reel Control Box
BC-614*	Amplifier, Speech, P/O SCR-299, -399, -499; TM 11-5054
BC-615	Relay Box
BC-616	Relay Junction Box
BC-617*	Receiver and Selector, 30-40 MHz FM, P/O RC-64 target controller
BC-618	Receiver, 200 MHz, P/O SCR-516 radar
BC-619	Antenna Tuner, for BC-441, P/O SCR-281; TM 11-244, 1944
BC-620*	Receiver-Transmitter, 20-28 MHz FM, P/O SCR-509, -510
BC-621	Transmitter, P/O SCR-516 radar
BC-622*	Relay Unit
BC-623	Modulator, P/O SCR-516 radar
BC-624*	Receiver, 100-156 MHz, four-channel, P/O SCR-522, -542, -574, -575, -624, AN/CRC-2 radio sets
BC-625*	Transmitter, 100-156 MHz, four-channel, 15 W AM, 832 final, P/O SCR-522, -542, -574, -575, -624 radio sets
BC-625-AM	Transmitter, P/O AN/CRC-2 radio set
BC-626	Control Box
BC-627	Control Unit
BC-628	Transmitter
BC-629*	Jack Box (pilot), P/O SCR-522 and -542 radio sets
BC-630*	Jack Box (crew interphone), P/O SCR-522 and -542 radio sets
BC-631*	Jack Box (crew), P/O SCR-522 and -542 radio sets
BC-632	Keying Unit
BC-633	Oscilloscope
BC-634	Oscilloscope
BC-635	Receiver
BC-637	Range Unit, Radar
BC-638	Frequency Meter, 100-156 MHz, U/W BC-639, SCR-522, -542, -574, -624; AN 08-40BC638-2, 1944
BC-639*	Receiver, rack-mounted, 100-156 MHz, P/O SCR-563, -564, -565, -574, -575, -633, -644, -645, AN/CRC-2
BC-640*	Transmitter, rack-mounted, 100-156 MHz, 40 W AM, P/O SCR-562, -573, -643; AN 08-40BC640-2, 1943
BC-641*	Amplifier
BC-642	Transmitter, 4-20 MHz, 3 kW AM-CW, 10 preset channels
BC-643	Modulator, U/W BC-642
BC-644	Transformer and Contactor, U/W BC-642
BC-645*	IFF Set, 435-500 MHz, 316A in xmtr, P/O SCR-515, like Navy ABA
BC-646*	Control Box, U/W BC-645
BC-647*	Transmitter, one 2C34 tube
BC-648*	Control Box, P/O SCR-535
BC-649	Impact Switch Box (see BC-706); AN 08-5-50, 11-42
BC-650*	Receiver
BC-651	Oscillator
BC-652	Receiver, 2-6 MHz (like Navy RAX), 12-24 V, P/O SCR-506

BC-653	Transmitter, 2-4.5 MHz, 100 W CW, 50 W AM, two 814 finals, 12-24 V, P/O SCR-506
BC-654*	Receiver-Transmitter, 3.8-5.8 MHz, 25 W, 307A finals, P/O SCR-284
BC-655	Transmitter, Target, portable, 17.5-158 MHz, dry-battery power, P/O RC-93, SCR-555, -575; TM 11-4050
BC-656	Receiver
BC-657	Transmitter
BC-658	Control Box, for BC-652 & -653, P/O SCR-506
BC-659*	Transceiver, 27-39 MHz, 2 W FM, P/O SCR-609, -610, AN/CRN-10
BC-660	Indicator
BC-661	Oscillator
BC-662	Oscilloscope
BC-663	Receiver, Mark IV long range IFF set, P/O SCR-533
BC-664	Transmitter
BC-665	Oscilloscope, 5BP4 CRT, P/O SCR-533
BC-666	Generator and Keying Unit, P/O SCR-553
BC-667	Interphone Amplifier (see BC-367), P/O RC--38 and 99; TM 11-702
BC-668	Modulator
BC-669*	Receiver-Transmitter, 1.65-4.45 MHz, 45 W, AM-CW, 807 finals, P/O SCR-543; TM 11-624
BC-670*	Remote Control Box, for RA-38, U/W SCR-268; TM 11-1053, 1944
BC-671	Receiver Output Box, P/O test equipment RC-68 for SCR-268
BC-672*	AC Outlet Box, P/O RC-68, for SCR-268
BC-673	Test Unit
BC-674	Radar Range Unit
BC-675	Radar Range Unit
BC-676	Receiver
BC-677	Transmitter; TM 11-1060, 1943
BC-678	Jack Box, P/O RC-53; TM 11-700
BC-679	Keying Unit
BC-680	Receiver and Oscilloscope Unit
BC-681	Transmitter
BC-682	Oscilloscope
BC-683*	Receiver, 27-39 MHz version of BC-603, P/O SCR-608, -628
BC-684*	Transmitter, 27-39 MHz version of BC-604; P/O SCR-608, -628; TM 11-628, -859, -4037
BC-685*	Relay Unit, P/O SCR-574 net control system
BC-686*	Remote Control & Line Amp, P/O SCR-561, -572, -574, -575, -642, -644, -645 network control systems
BC-687*	Relay Unit, P/O SCR-645 DF system; AN 08-40BC687-2, 1944
BC-688	Receiver, 515 MHz, P/O SCR-518 radar altimeter
BC-689	Transmitter, 515 MHz, two 8012s, P/O SCR-518 radar altimeter
BC-690	Control Box, P/O SCR-518 radar altimeter
BC-691	Radar Training Device, P/O RC-111
BC-692	Interphone Amplifier
BC-693	Receiver
BC-694	Receiver

BC-695	VHF Receiver, a W. E. Co. prototype evolving into the BC-942 and then the R-28/ARC-5
BC-696*	Transmitter, 3-4 MHz, 30 W, P/O SCR-274
BC-697	Transmitter
BC-698	Transmitter
BC-700	Receiver-Transmitter, P/O SCR-521
BC-701*	Receiver, 178-180 MHz, 30.5-MHz IF, 11 tubes, P/O SCR-521 radar
BC-702*	Transmitter, P/O SCR-521 radar
BC-703*	Control Panel for BC-702*
BC-704	Indicator, 5BP1 & 5FP7 CRTs, P/O SCR-521, TRS-1
BC-705	Manual Self-Destruction Switch, P/O SCR-515 IFF set
BC-706*	Impact Switch, for automatic demolition of SCR-515 IFF set
BC-707	Jack Box
BC-708	Test Unit
BC-709*	Interphone Amplifier, 3S4 tube & internal batteries, P/O RC-73
BC-710	Control Box
BC-711	Control Box
BC-712	Antenna Relay Unit
BC-713	Test Unit, P/O I-100
BC-714	Test Unit, P/O I-100
BC-715	Test Unit
BC-716	Receiver, P/O SCR-296 700-MHz coastal-defense fire-control radar
BC-717	Transmitter, P/O SCR-296 radar
BC-718	Oscilloscope, 3AP1 CRT, P/O SCR-296 radar
BC-719	Oscilloscope, 5HP1 CRT, P/O SCR-296 radar
BC-720	Modulator, P/O SCR-296 radar
BC-721	Transceiver, "handie-talkie," P/O SCR-585. Also see BC-611.
BC-722	Control Box
BC-723	Range Unit, P/O SCR-296 radar
BC-724	Power Drive, P/O SCR-296 radar
BC-725	Calibrator, P/O SCR-296 radar; TM 11-1048, 1942
BC-726	Calibrator, P/O SCR-296 radar; TM 11-1128, 1943
BC-727	Self-Destruction Indicator, P/O SCR-515 IFF set
BC-728*	Receiver, 2-5 MHz, 4 push-button channels, P/O SCR-593
BC-729*	Antenna Tuning Unit (like TN-339/GR), U/W BC-610 xmtr
BC-730*	Audio Limiting Amplifier, U/W BC-329 & T-4/FRC, later designated AM-864/U
BC-731*	Control Box, for 115-V motor, has AC voltmeter and fuses
BC-732*	Control Box, for BC-733 and AN/ARN-5 receivers, P/O RC-103
BC-733*	Localizer Receiver, 108.3-110.3 MHz, crystal-controlled, 14-28 V, WE Co., Crosley, et al., for RC-103 blind landing system. U/W I-101 indicator. R/B R-57/ARN-5 and R-89/ARN-5A.
BC-734	Control Box
BC-735	Control Box
BC-736	"Interference Reducer," 6 tubes, U/W BC-403
BC-737	Microphone Amplifier
BC-738*	Transmitter
BC-739	Interphone Control Box, P/O RC-99

BC-740	Receiver & Transmitter, 10 cm, P/O SCR-520 radar
BC-741	Indicator, P/O SCR-520 radar
BC-742	Pilot's Indicator, P/O SCR-520 radar
BC-743	Synchronizer, P/O SCR-520 radar
BC-744	Control Box
BC-745	Transceiver, 2-6 MHz, P/O SCR-511 field radio
BC-746*	Tuning Unit, U/W BC-745, P/O SCR-511
BC-747	Transmitter
BC-748	Modulator
BC-749	Receiver
BC-750	Indicator
BC-751	Transmitter, P/O AN/CRN-3
BC-752	Modulator and Bridge
BC-753	Course Detector Receiver, P/O AN/CRN-3
BC-754	Course Detector Receiver, P/O AN/CRN-3
BC-755	Field Intensity Meter
BC-756*	Control Box
BC-757	Control Unit
BC-758	Keying Unit, P/O SCR-270 radar
BC-759	Control Box, P/O SCR-270 radar
BC-760	Oscilloscope, P/O SCR-270 radar
BC-761	Signal Generator, P/O I-109, IE-55
BC-762	Oscilloscope
BC-763	Test Set
BC-764	Receiver
BC-765	Impact Switch Box, for automatic demolition of SCR-695 IFF set
BC-766	Oscilloscope
BC-767	Detonator Warning Unit, two red lamps, P/O SCR-695 IFF set
BC-768	Receiver, 493.5 MHz, P/O RC-100 IFF set
BC-769	Transmitter, P/O RC-100 IFF set
BC-770	Keying Unit, P/O RC-100 IFF set
BC-771	Frequency Meter
BC-772	Control Box
BC-773	Control Box
BC-774	Control Box
BC-775	Oscilloscope
BC-776*	Oscilloscope
BC-777	Indicator Box, P/O AN/CRW-3
BC-778*	Transmitter, life-raft ("Gibson Girl"), 0.5 MHz, P/O SCR-578 (later T-74A/CRT-3A with 8.364 MHz added). Equiv. of Navy TCY.
BC-779A	Receiver, 0.54-31 MHz, Hammarlund Super Pro; TM 11-866, 1943
BC-779B	Receiver, 1.2-40 MHz version of BC-779A
BC-780	Pulse Indicator, P/O SCR-270, -271 radars
BC-781	Indicator, P/O SCR-517 radar
BC-782	Relay Box
BC-783	Amplifier
BC-784	Amplifier
BC-785	Transmitter, 109 MHz, P/O SCR-270 radar; TM 11-1570

BC-786	Oscilloscope
BC-787*	Receiver, Hallicrafters S-27/S-36, 28-143 MHz; TM 11-867, 1953
BC-788*	Transceiver, 420-450 MHz, 6J6 xmtr, P/O SCR-718 radar altimeter
BC-789	Control Box
BC-790	Radar Training Device, P/O RC-110
BC-791	Recorder, Code, using inked paper tape
BC-792	Receiver, DF, 0.1-65 MHz, P/O SCR-504 "suitcase set"; TM-11-4060
BC-793	Radar Synchronizer
BC-794*	Receiver, 0.15-0.4 and 2.5-20 MHz version of BC-779A, P/O SCR-244; TM 11-866
BC-795	Transmitter
BC-796	Keying Unit
BC-797*	Transmitter, 100-156 MHz, 50 W, P/O SCR-641; TM 11-650
BC-798	Receiver
BC-799	Oscilloscope
BC-800*	Radar Beacon ("Rebecca"), P/O SCR-729, AN/APN-2, RC-192
BC-800A	Transmitter-Receiver, IFF Training Device, P/O RC-192
BC-901	Transmitter, P/O AN/CRN-11, AN/GRN-1
BC-902*	Transmitter, P/O RC-115 and SCR-241 navigation-aid system
BC-903	Receiver, 0.55-30 MHz, National NC-100A, P/O SCR-255 DF set
BC-904	Transmitter, P/O SCR-255 DF set; TM 11-861
BC-905*	Range Calibrator, P/O IE-13
BC-906*	Frequency Meter, IFF, 145-235 MHz, absorption-type, P/O IE-13, -46, -48, -50, -56; U/W BC-1066 and I-196 gen. TM 11-2623, 1944
BC-907	Antenna Tuning Unit
BC-908*	Amplifier, Facsimile, P/O RC-58
BC-909	Control Box
BC-910	S-Band Radar Test Set, P/O IE-30
BC-911	Switch Box
BC-912	Keying Unit, P/O SCR-582 radar
BC-913	Switch Box
BC-914*	Test Unit
BC-915	Control Box
BC-916	RF Unit
BC-917	Oscilloscope
BC-918*	Facsimile Recorder/Scanner, 12 VDC, U/W MC-308B writing stand, P/O RC-58
BC-919	Control Box
BC-920	S-Band Radar Test Set, P/O IE-30
BC-921	Transfer Selector
BC-922	Modulator, P/O SCR-582 radar
BC-923	Receiver, 27-39 MHz FM, dual conversion, with 100-kHz calibrator, 12-24 V, P/O SCR-808, -828
BC-924	Transmitter, 27-39 MHz, FM, 12-24 V, 815 final, P/O SCR-808, -828
BC-925*	Modulator and Transmitter
BC-926	Amplifier, P/O SCR-582 radar
BC-927	Antenna Relay Unit
BC-929*	Radar Oscilloscope, 3BP1 CRT, P/O SCR-729, AN/APN-2Y

	200-MHz beacon homing sets; R/B ID-169B/APN-12
BC-930	Test Set
BC-931	B-Scope Indicator, 5FP7 CRT, P/O SCR-517 radar
BC-932	Indicator Amplifier for BC-931, P/O SCR-517 radar
BC-933	Transmitter
BC-934	Training Unit
BC-935	Relay Box
BC-936*	Indicator, P/O AN/APN-2, IE-36, IE-56
BC-937	PPI Indicator, 14-V ("voltage regulator" in TB SIG 5-1)
BC-938	A-Scope, U/W BC-937
BC-938	Control Box, U/W SCR-274N HF-VHF radios (TB SIG 5-1)
BC-939	Antenna Tuner, U/W T-368*/URT in AN/GRC-26; TM 11-809
BC-940	Control Unit
BC-941	Range Unit, P/O SCR-547 radar
BC-942	Receiver, 100-156 MHz, P/O SCR-274N, WE Co., predecessor of R-28/ARC-5
BC-943	Control Box
BC-944*	Control Box
BC-945	Indicator Box
BC-946*	Receiver, 0.52-1.5 MHz, P/O SCR-274N
BC-947	Transmitter, 10-cm, 1 kW, WE Co., P/O SCR-547 radar
BC-948	Receiver
BC-949	Range Calibrator, P/O IE-56; TO 33A1-10-4-2
BC-950*	Transmitter, predecessor of T-23/ARC-5, WE Co., P/O SCR-274N
BC-951	Filter Unit
BC-952	Receiver, P/O SCR-582 radar
BC-953	Training Unit, P/O SCR-582 radar
BC-954	Oscilloscope, P/O SCR-582 radar
BC-955	Control Unit, P/O SCR-517 radar
BC-956	Oscilloscope, P/O SCR-582 radar
BC-957	Receiver-Indicator, 5HP4 CRT, P/O SCR-547 radar
BC-958*	Power Control Box, P/O SCR-695 IFF set; TM 11-1062, 1944
BC-959	Antenna Tuning Unit
BC-960	Control Box
BC-961	Antenna Switching Unit, P/O SCR-521 radar
BC-962	Switch Box
BC-963	Receiver
BC-964	Transmitter, P/O SCR-274N?
BC-965*	Control Box (Selector), P/O SCR-695 IFF set
BC-966*	Transponder, 160-211 MHz (four 7193s; 3 units in B-25), P/O SCR-695 IFF
BC-967	Receiver, 18-156 MHz, P/O SCR-613
BC-968	Training Device for SCR-268, -270, -271 radars
BC-969*	Receiver, 0.015-0.15 MHz, P/O SCR-614; TM 11-873, 1943
BC-970	Transmitter
BC-971	Receiver
BC-972	Control Box
BC-973*	Receiver, DF, 1-3 MHz, P/O SCR-503; TM 11-246

BC-974	Receiver
BC-975	Indicator Box
BC-976*	Receiver, 2-20 MHz, P/O SCR-551
BC-977	Receiver, radar search, 38-3300 MHz, P/O SCR-587
BC-978	Target Transmitter, P/O SCR-551; TM 11-4004
BC-979	Antenna Control Unit
BC-980	Antenna Receiver, radar
BC-981	Antenna Receiver, P/O SCR-527, -627 radars
BC-982	Transmitter, FTR Co. P/O SCR-527, -627 radars
BC-983	Modulator, P/O SCR-527
BC-984	Modulator, P/O SCR-584, -784 radars
BC-985	Keyer, P/O SCR-527, -627 radars
BC-986*	A-Scope, P/O SCR-270, -271, -627 radars
BC-987	PPI Indicator, 12DP7 CRT, P/O SCR-527, -627 radars
BC-988	Calibrator, P/O SCR-270, -271, -527, -627 radars
BC-989	Oscillator, P/O SCR-527, -627 radars
BC-990	Relay Unit
BC-991*	Oscilloscope, P/O SCR-551
BC-992	Indicator, 3EP1 CRT, P/O SCR-517 radar
BC-993	Synchronizer, 3EP1 CRT, P/O SCR-517 radar
BC-994	Control Box
BC-995	Servo Amplifier, P/O SCR-517 radar
BC-996	Interphone Amplifier
BC-997	Receiver
BC-998	Receiver and Selector
BC-999	Modulator and Transmitter
BC-1000	Transceiver, back-pack or mobile, 40-48 MHz FM, P/O SCR-300, AN/VRC-3; TM 11-637
BC-1001*	Receiver
BC-1002	Analyzer
BC-1003*	Receiver, DF, 0.1-1.0 MHz, P/O SCR-503; TM 11-246
BC-1004*	Receiver, Hammarlund Super-Pro, P/O SCR-244; TM 11-866
BC-1005	Receiver, DF, 18-145 MHz, P/O SCR-555; TM 11-251
BC-1006	Receiver, DF, 65-156 MHz, P/O SCR-556; TM 11-255
BC-1007*	Modulator, P/O SCR-717 radar
BC-1008	Control Box
BC-1009	Control Box
BC-1010	Receiver
BC-1011*	Control Unit
BC-1012*	Control Unit
BC-1013	Control Unit
BC-1014	Transmitter
BC-1015	Range Indicator, Radar
BC-1016	Recorder, Code, using inked paper tape; TM 11-441
BC-1017	Transmitter, Radar Jamming (later T-26/APT-2), P/O RC-156
BC-1018	Receiver
BC-1019	Interphone Amplifier
BC-1020	Receiver & Transmitter

BC-1021	Oscilloscope
BC-1022	Control Unit
BC-1023	Marker-Beacon Receiver, 75 MHz, three tubes, P/O RC-193; AN 08-10-150 Also see BC-1033.
BC-1024	Frequency Reducer (converter?)
BC-1025	Receiver & Transmitter
BC-1026	Relay Box
BC-1027	Oscilloscope
BC-1028	Transmitter
BC-1029	Receiver & Transmitter
BC-1030	Transmitter
BC-1031*	Panoramic Adapter, P/O TC-8 DF set; TM 11-446, 1944
BC-1032*	Panoramic Adapter, for receivers with 5.25-MHz IF, P/O SCR-607; TM 11-446, 1944
BC-1033*	Marker-Beacon Receiver, 75 MHz, P/O RC-193; AN 08-10-157. Also see BC-1023.
BC-1034	Control Unit
BC-1035	Oscilloscope, 5CP1 CRT, P/O SCR-545 radar
BC-1036	Control Unit
BC-1037	Transmitter
BC-1038	Receiver
BC-1039	Transmitter
BC-1040	Receiver & Transmitter, P/O SCR-520 radar
BC-1041	Indicator, 5FP7 CRT, P/O SCR-520 radar
BC-1043	Synchronizer, P/O SCR-520 radar
BC-1044	Control Box, P/O SCR-520 radar
BC-1045	Synchronizer, P/O SCR-520 radar
BC-1046	Relay Box
BC-1047*	Control Unit
BC-1048	CRT Deflection Unit
BC-1049*	Control Unit
BC-1050	Receiver & Transmitter, P/O SCR-517 radar
BC-1051	Control Unit
BC-1052*	Test Set, multimeter, P/O SCR-299, -399, -499; 1943
BC-1053	Range Unit, P/O SCR-545 radar
BC-1054	Control Box, P/O SCR-545 radar
BC-1055	Receiver, P/O SCR-545 radar
BC-1056*	Receiver, P/O SCR-584, -784 radars
BC-1057	Receiver, P/O SCR-545 radar
BC-1058*	PPI Indicator, P/O SCR-584, -784 radars
BC-1059	Control Unit, P/O SCR-545 radar
BC-1060*	Oscilloscope, 3GP1 CRT, P/O RC-283 IFF Set; TM 11-2526, 1944
BC-1061	Control Unit
BC-1062*	Range Computer, P/O SCR-584, -784 radars
BC-1063	Control Unit
BC-1064	Receiver & Transmitter, P/O SCR-621, RC-201
BC-1065	Control Unit
BC-1066*	Receiver, G- & I-band IFF test, P/O IE-46, -56, U/W BC-906, I-196

BC-1067*	Control Unit, IFF, 150-200 MHz, 1 kW, P/O RC-145
BC-1068	Receiver, IFF, 175-200 MHz, U/W SCR-268, TM 11-1117. Similar to Navy BN receiver.
BC-1069	Amplifier, IFF, P/O SCR-545 radar
BC-1070*	Training Device (later AN/UPS-T2) for SCR-268, -270, -271 radars
BC-1071	Amplifier, Range Indicator, P/O SCR-784 radar
BC-1072	Transmitter, IFF, 155-185 MHz, 115 V, two 826s
BC-1073*	Wavemeter, 150-210 MHz, U/W BC-1068
BC-1074*	Remote Video Amplifier, P/O SCR-584, -784 radars
BC-1075*	Altitude Data Unit, P/O SCR-584, -784 radars
BC-1076*	Antenna Position Indicator, P/O SCR-584, -784 radars
BC-1077*	Signal Generator, P/O IE-57. Also see BC-1277.
BC-1078*	RF Preamplifier, P/O SCR-584, -784 radars
BC-1079	Oscillograph
BC-1080*	Transmitter Driver Unit, P/O SCR-584, -784, AN/MSQ-1 radars
BC-1081	Transmitter, 212 MHz, P/O SCR-602 radar
BC-1082	Receiver, P/O SCR-602 radar
BC-1083	Oscilloscope, P/O SCR-602 radar
BC-1084	Oscilloscope, 5GP1 CRT, P/O SCR-602 radar
BC-1085	Antenna Control Unit, P/O SCR-584, -784 radars
BC-1086*	Tracking Unit, P/O SCR-584, -784 radars
BC-1087	Oscilloscope, 3BP1 CRT, P/O IE-57, AN/APM-7. Also see BC-1287.
BC-1088	Range Indicator (two 3DP1 CRTs), P/O SCR-584, -784 radars
BC-1089	Indicator, P/O SCR-584, -784 radars
BC-1090*	Azimuth & Elevation Tracking Unit, P/O SCR-584, -784, AN/MSQ-2 radars
BC-1091*	RF Unit, P/O SCR-717 and -720 S-band radars
BC-1092*	PPI Display, P/O SCR-584, -784 radars
BC-1093	Indicator, P/O SCR-717 radar
BC-1094*	Altitude Converter, P/O SCR-584, -784 radars
BC-1095	Synchronizer, P/O SCR-717 radar
BC-1096*	Oscillator, 2680-3300 MHz, P/O SCR-584, -784 radars
BC-1097	Control Unit
BC-1098	Coder Unit, 2AP1 CRT, P/O RC-232, SCR-621, -640 radar beacons
BC-1099	Trainer Set
BC-1100	Transmitter, 1.5-10 MHz, 75/50 W, crystal control, P/O RC-263
BC-1101	Indicator, like BC-1041, P/O SCR-517 radar
BC-1102	Range Converter (same as BC-1053), P/O SCR-545 radar
BC-1103	Control Box
BC-1104	Control Unit
BC-1105	Calibrator, P/O SCR-588, -636 radars
BC-1106	Receiver, Radar
BC-1107	Radar Computer
BC-1108	Control Box
BC-1109	Test Oscillator
BC-1110	Antenna Relay
BC-1111	Indicator, 12EP1 CRT, P/O SCR-588 radar

BC-1112	Monitor, P/O SCR-588 radar
BC-1113	Control Unit, P/O SCR-597 transmitter
BC-1115	Receiver
BC-1116	Transmitter
BC-1117	Transmitter
BC-1118	Receiver
BC-1119	Control Unit
BC-1120	Coupling Unit
BC-1121	Receiver, P/O SCR-588 radar
BC-1122	Amplifier, P/O SCR-588 radar
BC-1123	Amplifier, P/O SCR-588 radar
BC-1124	Oscillator, P/O SCR-588 radar
BC-1125	Oscillator, P/O SCR-588 radar
BC-1126	RF Head Unit, P/O SCR-588 radar
BC-1127	Transmitter, P/O SCR-588 radar
BC-1128	Control Box, P/O SCR-588 radar
BC-1129	Modulator, P/O SCR-588 radar
BC-1130	Crystal Mixer, P/O SCR-584, -784 radars
BC-1131	Modulator, P/O SCR-584, -784 radars
BC-1132	T-R Box, P/O SCR-584, -784 radars
BC-1133	Transmitter, P/O SCR-584, -784 radars
BC-1134	Switching Unit, P/O SCR-597 transmitter
BC-1135	Indicator, 12DP7 CRT, P/O SCR-597 2-20 MHz transmitter
BC-1136*	Receiver & Transmitter
BC-1137*	Receiver
BC-1138	Grid Control Unit
BC-1139	Relay Unit, P/O SCR-597, -636
BC-1140*	Control Box
BC-1141*	Amplifier, P/O SCR-625 mine detector
BC-1142	Modulator, P/O SCR-717, -720 radars
BC-1143	Radio Compass Unit
BC-1144	Control Box
BC-1145	Control Unit, P/O SCR-729 IFF set
BC-1146	Antenna Coupling Unit
BC-1147*	Receiver, DF, 1.5-30 MHz, P/O SCR-502; TM 11-256
BC-1148*	Synchronizer, P/O SCR-717, -720 S-band radars
BC-1149*	Target Transmitter, 2-10 MHz; TM 11-849, -4040
BC-1150*	Control Box, P/O SCR-717, -720 radars
BC-1151	Operator's Indicator, two 5FP7 CRTs, P/O SCR-717, 720 radars
BC-1152	Pilot's Indicator, 3HP7 CRT, P/O SCR-720 radar
BC-1153*	Indicator, two 5FP7 CRTs, P/O SCR-717 radar
BC-1154	Modulator
BC-1155*	Synchronizer, P/O SCR-717 radar
BC-1156*	Control Box, for AZON glide bomb
BC-1157*	Control Box
BC-1158*	Modulator & Transmitter, 53-95 MHz, 50 W, P/O RC-186
BC-1159	Bearing Indicator, 5BP1 CRT; TM 11-243
BC-1160	IFF Transmitter, 157-187 MHz, 1 kW pulse output

BC-1161	IFF Receiver, 150-200 MHz, U/W BC-1072; TM 11-1117
BC-1162	Wavemeter and Control Box, U/W BC-1161
BC-1163	Control Box
BC-1164	Control Box
BC-1165	Control Box
BC-1166	Calibrator
BC-1167	Amplifier, P/O IE-57, AN/APM-37 airborne-radar test equipment
BC-1168	Sound-Ranging Radio Link
BC-1169	Receiver & Transmitter, P/O RC-232
BC-1170	Interference Reducer
BC-1171	Control Box, P/O SCR-624 radio. Also see BC-1314.
BC-1172	Receiver
BC-1173	Oscilloscope
BC-1174	Indicator
BC-1175	Control Box, P/O SCR-522-type radios
BC-1176	Control Box, P/O SCR-522-type radios
BC-1177	Trainer
BC-1178	Trainer
BC-1179	Receiver
BC-1180	Frequency Meter
BC-1181	Recorder
BC-1182*	Receiver, P/O SCR-722
BC-1183	Control Box
BC-1184	Oscilloscope, 5CP1 CRT, P/O RC-252
BC-1185	Receiver & Selector
BC-1186	Transmitter, P/O SCR-636
BC-1187	Modulator
BC-1188	Antenna Switch, P/O SCR-636
BC-1189	Control Box
BC-1190	Receiver
BC-1191	Transmitter
BC-1192	Transmitter
BC-1193	CRT Indicator Control Unit, P/O SCR-682 radar and IFF set
BC-1194	Modulator, P/O SCR-682 10-cm radar; TM 11-1561
BC-1195	Discriminator
BC-1196	Indicator
BC-1197	Computer, Radar
BC-1198	Control Unit
BC-1199	Control Unit
BC-1200	Capacitor Unit
BC-1201	Diode Probe Coupling Head, P/O IE-45
BC-1202	Diode Probe Coupling Head, P/O IE-45
BC-1203*	Amplifier-Modulator, LORAN, P/O IE-45, for testing AN/APN-4
BC-1204	Adaptor, for training use of BC-642 control boxes of RC-56 remote control
BC-1205	Steering Indicator
BC-1206*	Beacon Receiver, 0.2-0.42 MHz, 28-V heaters and B+, Setchell-Carlson Model 524

BC-1207 Indicator Box
BC-1208 Oscillator
BC-1209 Receiver & Transmitter
BC-1210 Control Box
BC-1211-T1, T2 Airborne TV Camera, 1848 iconoscope, 14-V, includes 100-MHz transmitter with 829 final; P/O SCR-549 TV system
BC-1211-T4 Airborne TV Camera, 1846 iconoscope, 28-V, U/W BC-1212 transmitter, P/O SCR-549 TV system
BC-1212* Transmitter, 260-320 MHz, 28 V, 8025 final, P/O SCR-549
BC-1213-T1, T2 Receiver-monitor, TV, airborne, 14 V, 100 MHz, P/O SCR-550
BC-1213-T3 Receiver-monitor, TV, airborne, 28 V, 260-320 MHz, P/O SCR-550
BC-1214 Monitor Unit, 7" CRT, P/O SCR-550 receiver for airborne TV. -T1 and -T2 models used 14 V; T3, 28 V.
BC-1215 Calibrator
BC-1216 Compensation Unit
BC-1217 Control Box
BC-1218 Modulator
BC-1219 RF Unit
BC-1220 Indicator Unit
BC-1221 Modulator
BC-1222 Antenna Drive
BC-1223 Receiver, P/O SCR-682 radar; TM 11-1561
BC-1224 Transmitter, P/O SCR-682 radar
BC-1225* Indicator, P/O SCR-682 radar
BC-1226 Control Unit
BC-1227 Oscilloscope, P/O SCR-627 radar
BC-1228 Switch Box
BC-1229 Adapter Box
BC-1230 Control Box
BC-1231 Oscillator
BC-1232* Receiver, Radar, 90-120 MHz, P/O SCR-270, -271, R/B BC-1310
BC-1233 Oscilloscope; TM 11-1066, 1944
BC-1234 Oscilloscope
BC-1235 Signal Generator
BC-1236 Signal Generator
BC-1237 Transmitter, Radar Jamming, P/O RC-183
BC-1238 Control Box
BC-1239 Receiver-Indicator, 12DP7 & 12DP8 CRTs, P/O SCR-270, -271
BC-1240 Transmitter
BC-1241* RF Unit, P/O SCR-615A radar; TM 11-1541
BC-1242* Modulator, P/O SCR-615A
BC-1243 Local Oscillator, one 417A klystron, P/O SCR-615A radar
BC-1244 A- and R-Scopes, P/O SCR-615A
BC-1244-A Indicator Unit, 5CP7 CRT, P/O SCR-615A radar
BC-1245 PPI Oscilloscope, 7" CRT, P/O SCR-615A radar
BC-1246* Receiver, P/O SCR-615A
BC-1247* Preamplifier, three 6AC7s, P/O SCR-615A radar
BC-1248 PPI Control Unit, P/O SCR-615A

BC-1249	Altitude Indicator, P/O SCR-615A radar; TM 11-1541
BC-1250	Error Unit, P/O SCR-615-T1 radar trainer
BC-1251	Synchronizer, P/O SCR-615A radar
BC-1252*	Console, P/O SCR-615A radar
BC-1253	Transmitter, Radiosonde, 397 MHz
BC-1254	Test Unit
BC-1255	Heterodyne Test Receiver, 75-150 MHz, P/O RC-183
BC-1256	Antenna Control
BC-1257	Control Box
BC-1258*	Amplifier
BC-1259	Oscilloscope
BC-1260	Receiver
BC-1261	Control Unit
BC-1262*	Monitoring Unit
BC-1263	Switching Unit
BC-1264*	Control Cabinet
BC-1265	Control Box
BC-1266	Control Unit & Monitor, 5CP1 CRT, U/W I-22A, P/O RC-145A
BC-1267	Receiver-Transmitter, 157-187 MHz, two 2C26s in transmitter, 1 kW peak, Belmont Radio, for RC-127, -145, -184, -188, -350 IFF sets; U/W I-221 indicator
BC-1268	Control Unit, 5CP1 CRT, P/O RC-184
BC-1269	Monitoring Receiver, 145-600 MHz AM-FM (later R-593/GRR), P/O SCR-615
BC-1270	Discriminator, P/O SCR-270, -271 radars
BC-1271	Receiver, 100-156 MHz, P/O SCR-641; TM 11-650
BC-1272	Control Box
BC-1273	Relay Unit
BC-1274	Relay Unit
BC-1275	Beacon Simulator
BC-1276	RF Unit, X-Band, WE Co., P/O SCR-667 and AN/APQ-13
BC-1277	Signal Generator (IE-57B), like BC-1077
BC-1278	Control Box
BC-1279*	Short-Gate Control Unit, P/O SCR-615A radar
BC-1280	Signal Generator & Oscilloscope
BC-1281	Receiver
BC-1282*	Data Transmitter
BC-1283*	Data Receiver
BC-1284	Preamplifier, Lighthouse Tube, for BC-1269, P/O SCR-616
BC-1285*	Antenna Control Unit
BC-1286	Control Unit
BC-1287	Oscilloscope, 3BP1 CRT, P/O IE-57, AN/APM-37 radar test set
BC-1288	Frequency Meter
BC-1289	Preamplifier
BC-1290	Tone Generator
BC-1291	Motor Control Box
BC-1292	Amplifier & Record Player, P/O Public Addrsss Set PA-5
BC-1293*	Control Unit, 5CP1 CRT, P/O RC-127 & -350 IFF sets

BC-1294	Modulator
BC-1295	Error Indicator Oscilloscope
BC-1296	Control Unit
BC-1297	Data Transmitter
BC-1298	Interconnector
BC-1299	RF Amplifier
BC-1300	Interphone Amplifier
BC-1301	Remote Control Unit
BC-1302	Control Unit
BC-1303	Control Unit, P/O IE-36, for testing SCR-522
BC-1304	Oscillator
BC-1305	Resonance Tuner
BC-1306	Receiver-transmitter, 3.8-6.5 MHz CW-AM, P/O SCR-694; TM 11 -694, -2603, -2300, -4009
BC-1307	Control Box
BC-1309	Impulse Control Unit
BC-1310	Receiver, 90-120 MHz, 30-MHz IF, P/O SCR-270, -271 radars
BC-1311*	Amplifier, P/O AN/TRC-9
BC-1312	Control Box
BC-1313	Control Box
BC-1314	Control Box (improved BC-1171), P/O SCR-624A ground radio
BC-1315	Master Console, P/O RC-270 radar trainer
BC-1316	Console
BC-1317	Receiver, P/O RC-270 radar trainer, U/W BC-1315, 1943
BC-1318	Receiver
BC-1319	Control Unit
BC-1320	Master Cathode Follower
BC-1321	Voltage Regulator
BC-1322	Amplifier
BC-1323*	Recorder, P/O Sound Locating Set GR-6-A; TM 11-2552, 1951
BC-1324	Discriminator
BC-1325	Discriminator
BC-1326	Sector Scan Unit, Radar
BC-1327	Modulator
BC-1328	Charging Transformer Unit
BC-1329	Transformer Unit
BC-1330	Data Plotter
BC-1331	Range Data Transmitter
BC-1332	Transmitter
BC-1333	Receiver
BC-1334	Amplifier
BC-1335	Transceiver, 27-39 MHz FM, P/O SCR-619; TM 11-879, 1945
BC-1336	Receiver-Transmitter
BC-1337	Recorder (Teledeltos paper), P/O Sound Ranging Set GR-8; TM 11-2568
BC-1338	Bearing Indicator
BC-1339	Discriminator Kit
BC-1340	Discriminator Kit

BC-1341	Hand Control Unit
BC-1342	Control Box
BC-1343	Discriminator
BC-1344	Discriminator Kit
BC-1345	Receiver & Transmitter
BC-1346	Control-Amplifier Unit, P/O Public Address Set PA-8; TM 11-2564
BC-1347	Transmitter
BC-1348	Monitor Oscilloscope
BC-1349	RF Unit
BC-1350	Local Oscillator
BC-1351	Crystal Mixer
BC-1352	Preamplifier
BC-1353	Console
BC-1354	Console
BC-1355	Azimuth-Elevation Indicator
BC-1356	Indicator Unit
BC-1357	Antenna Position Control
BC-1358	Receiver
BC-1359	Range Indicator Oscilloscope
BC-1360	Console
BC-1361	Interphone Control Box, for tanks, P/O RC-298; TM 11-702; 1949
BC-1362	Interphone Box, External, for tanks, using H-22 handset, P/O RC-298; TM 11-703
BC-1363	Remote Indicator
BC-1364	Receiver-Indicator, Radiosonde, 392-413 MHz FM; TM 11-1158
BC-1365	Indicator-Tracking Unit, P/O SCR-682A radar
BC-1366*	Jack Box, for aircraft receivers & transmitters
BC-1367	Control Box
BC-1368	Control Unit
BC-1369	Interphone Box
BC-1370	Indicator Control Unit
BC-1371	Range Indicator
BC-1372	Range Tracking Unit
BC-1373	Transmitter, P/O SCR-784 radar
BC-1374	Oscillator, 2000 MHz, P/O SCR-784 radar
BC-1375	Discriminator
BC-1376	Control Box
BC-1377	Receiver
BC-1378	CRT Display, P/O SCR-784, RC-384 157-187 MHz IFF Set
BC-1379	Receiver
BC-1380	Transmitter
BC-1381	Discriminator
BC-1382	Receiver-Transmitter
BC-1383	Control Rack Unit
BC-1384	Servo Amplifier
BC-1385	Signal Monitor, U/W BC-779 receiver
BC-1386	Receiver-Indicator-Synchronizer, radar
BC-1387	Coupling Unit

BC-1388	Audio Amplifier, for phone-line testing; TM 11-2556, 1945
BC-1389	Timing Unit
BC-1390	Radar Receiver
BC-1391	Radar Receiver
BC-1392	Sweep Amplifier
BC-1393	RF Stabilizing Unit
BC-1394	Remote Tuner Unit
BC-1395	Frequency Divider
BC-1396	Driver Unit
BC-1397	Receiver-Transmitter, P/O SCR-584 (MC-607A modification)
BC-1398	Radar Receiver, 8500-9600 MHz
BC-1399	Video Amplifier
BC-1400	PPI Unit
BC-1401	PPI Unit, P/O SCR-584 (MC-607A modification)
BC-1402	Control Unit
BC-1403	Range Indicator
BC-1404	Flight Simulator
BC-1405	Height Meter
BC-1406	Range Unit
BC-1407	Sector Scan Unit
BC-1408	Amplifier
BC-1409	Control Rack Unit
BC-1410	Data Unit
BC-1411	Control Unit
BC-1420	Frequency Meter for BC-1421, P/O RC-256; TO AN-0810-227
BC-1421	Receiver, 100-156 MHz AM/CW, 11 tubes, Hazeltine, P/O RC-256

REFERENCES (PARTIAL)

Storage Catalog - Signal Corps (Washington: U. S. Government Printing Office, 1920), pp. 15-16, 33-34, 148, 153-155, 501-561.

The Principles Underlying Radio Communication, 2nd Ed., Radio Communication Pamphlet No. 40, Signal Corps, U. S. Army (Washington: U. S. Government Printing Office, 1922), pp. 447, 575-576.

"Radio Set Technical and Descriptive Information," Electrical Communication Systems Engineering, War Department Technical Manual TM 11-486, 1945, pp. 355-370.

Directory of Signal Corps Equipments - Radio Communication Equipment, Department of the Army Technical Manual TM 11-487A, August 1950.

Schematic Diagrams for Maintenance of Ground Radio Communication Sets, War Department Technical Manual TM 11-486, 1943

"Radar" and "Major Wartime Radio Equipment," in M. D. Fagen, ed., A History of Engineering and Science in the Bell System - National Service in War and Peace (1925-1975) (Murray Hill, NJ: Bell Telephone Laboratories, Inc., 1978), pp. 19-132 and 319-334.

Frederick W. Chesson

Fred Chesson came to the Electron Art via a Tesla-coil construction article in the January, 1946 issue of Popular Science, when he was 16. The Tesla coil was duly built, using such diverse parts as an oatmeal box, the bakelite base of a (now highly desirable) Kennedy battery radio, a UTC power transformer from the Heath Company, and a surplus VT-25. Some 40 years later the coil came from the attic to take third place in an AWA equipment contest.

He graduated from the University of Connecticut in 1952 with a BA in Physics, then worked as an electronics engineer for about 20 years before gravitating into technical writing. His historical interest in Signal Corps designations goes back to younger days, when he made elaborate equipment lists from the exciting pages of Radio News and Radio Craft. Acquiring a personal computer made an SCR-RC-BC data base possible.

When not involved in arcane antiquities like a definitive listing of all known BC-control boxes, he does historical and travel articles, plus long-term research ranging from a study of Connecticut's war against tuberculosis, to Civil War ciphers and telegraph history, the lost iron industry, and various fiction projects.

WHO INVENTED THE SUPERHETERODYNE?[1]

Robert Champeix
Saint-Cloud, France
Translated by **Richard Foster**
Wayland, MA

INTRODUCTION

The birth of the superheterodyne gave rise to bitter controversy in the years 1925 and 1926. Our friend Robert Champeix has been good enough to sum up in a few pages the principal aspects of the problem. Thanks are due him, for this subject is a delicate one.

Our purpose in publishing this work is not to rekindle quarrels and emotions which have long lain quiet, but to show via this example just how difficult it is to establish a historical truth in science or technology.

The origin of any invention, the terms used in articles and in patents to define the purposes may vary with the authors who may be so full of their subject as to forget to give a precise definition, thereby inadvertently bringing new meaning to an old term, not having foreseen all the possible applications. One can also imagine the distortions of meaning introduced by translations.

Between the conception of a new idea and its special vocabulary, and its final acceptance as truth, many years may pass. In between, there are often dialogs between deaf persons, even persons of good faith, especially those who are touchy on the subject.

FOREWORD

One day in January 1968, the author happened to be at the Maison de la Radio, where he was taking a part in setting up the French Radio and TV's museum. Pierre Sabbagh had spoken some time earlier during a special broadcast to people who might have old radio apparatus, asking them to make donations or loans to the museum. This call was heard by many former "wireless" men.

This is how we saw the arrival of a gentleman, elderly but elegant, who introduced himself as Paul Laüt. This name was not unfamiliar to me, but the memories were not clear. It was then that he said to me "I was part of Colonel Ferrié's team during the 1914-18 war." Overjoyed to meet one of the few survivors of this heroic time, I asked him about many things. He was glad to answer me.

By chance during the conversation he made an astonishing statement: "I was the first to have the idea of reception by frequency conversion." I already knew, like most who are interested in the history of radio, about the dispute which had opposed Lucien Lévy and Edwin Armstrong over priority in the invention of the superheterodyne. Was there a "third man"? I asked Mr. Laüt to explain, which he did enthusiastically. Obviously he was very wrapped up in the subject.

> "I was mobilized in August, 1914. I was 24 years old. Since I was an electrical engineer, I was assigned to the team of Colonel Ferrié at the

1. Originally published in the *Liaison des Transmissions*, No. 116 (March-April 1979) and No. 117 (May-June 1979). Reprinted in English by permission.

Eiffel Tower. I took an active part as early as the beginning of 1915 in the development and fabrication of the first apparatus using the TM tubes which had just been developed by Professor Abraham's group in Lyon.

In 1916 I fell seriously ill with tuberculosis. The Army sent me to the Berck Sanatorium, where I spent a year. As my illness did not impair my intellectual activity, Colonel Ferrié assigned various subjects to me. It was thus that I established the theory of the function of three-element vacuum tubes.

The military telegraphy [organization] had just developed the first heterodynes designed to render audible, thanks to beats, telegraphic transmissions in continuous waves. While studying reception using heterodynes, I had the idea of using these to obtain, by beating them with the wave to be received, oscillations at lower but still inaudible frequencies which could then be easily amplified. On the first of February 1917, I wrote a note that I sent to Colonel Ferrié, who, as it was required in the service, sent a copy to all his assistants.

Once back on my feet and back at the Eiffel Tower in the end of 1917, I was not a little surprised to learn that Lucien Lévy, who was also a member of the Ferrié team, had taken out a patent, during August, on an invention that was nothing less than the one that I had described in my note of February 1.

Naturally I lodged a protest with the Colonel, but he did not like difficulties. He reminded me that we were at war and that any disagreements between French scholars or engineers would be out of place. I did not press the matter, but later, in 1926, I had the satisfaction of seeing my priority recalled by the review *L'Antenne*."

PART ONE: THE IDEAS

THE PRINCIPLES

To retrace the history of the superheterodyne,[2] one must first review the principles. We beg the indulgence of readers who are already familiar with what is to follow.

Between 1910 and 1920, wireless used virtually nothing but wavelengths greater than 1000 meters: their propagation being nearly without anomalies meant that they were reliable. Quickly, however, the crowding of the airways led to research into the use of shorter wavelengths, since the number of channels that can be squeezed into a given bandwidth is proportional to the mean frequency of the band. At the same time attempts were made to increase the sensitivity of receivers in order to augment the range of radiotelegraphic communications.

---

2. Let us outline a point of grammar here. The word "superheterodyne" is formed from *super* (above) and *heterodyne* [heteros = other, dyne = force]. The word "force" being feminine (the same as the unit of measure of force, the dyne), radioelectricians have naturally given the feminine gender to *heterodyne*. Logically, they should have done the same thing for *super heterodyne*, and some people have actually done so, but, when mention was made of a *superheterodyne*, the understanding was "receiver." The result was that the masculine gender was finally accepted as usage. The 20th Century Larousse ratified this tradition.

The first idea, of course, was to use the newly created triodes (see [3] for the invention of the triode) and to multiply the number of stages of amplification using these triodes. Progress in this direction soon ran into a snag: the fact that the amplifier began to oscillate internally because of the built-in capacities either between tubes or between the grid and the plate of an individual tube. This nullifying factor was the more bothersome as the frequency of the wave to be received was higher.

It was possible to use shielding to prevent inter-tube regeneration; there was nothing to be done about the inter-electrode capacities of the tube itself. It was not until much later, about 1924 or 1925, that the "neutrodyne" method was used to counteract this problem, and finally the screen-grid tube.

The fundamental principle of reception by frequency conversion ("superheterodyne") consisted of causing the oscillation F_1 received by the antenna to beat with a local oscillator (a heterodyne) of frequency F_2, and thus to obtain a signal of intermediate frequency $F = F_1 - F_2$ much lower than the frequency F_1 of the incoming wave, this frequency being much more easily amplified than F_1 since the troublesome capacities had a relative influence on the frequency F that was much less than they would have had on F_1.

After amplification, a classic detector revealed the audible frequencies which modulated the intermediate frequency F in the same way they originally modulated the incoming F_1.

Let us recapitulate the characteristics and the advantages of reception by frequency conversion:

A) Very high sensitivity resulting:

- From the possibility of obtaining very high gain in the intermediate amplifier;
- From the possibility of a reasonable degree of amplification before the frequency changer without the risk of having the two amplifiers interact since their frequencies are very far apart;
- From the gain inherent in the injection of a heterodyne;
- From a greater efficiency of the final detection since this detector is working at a high signal level.

B) Simplicity of tuning due to the fact that the intermediate-frequency amplifier is tuned once and for all, while tuned radio frequency amplifiers require tuning of each amplifying stage for each frequency to be received.

C) Excellent selectivity because the method allows the augmentation of the number of tuned circuits as well as the use of a loop as a wave collector.[3]

We will not discuss the disadvantages of the first superheterodynes (numerous interference points at audible frequencies and thus whistles) because they were worked out later on. These disadvantages were judged to be serious enough at the time that the TRF circuit had fierce partisans for many years.[4]

---

3. It should be noted that, contrary to certain formerly accepted ideas, the improvement of selectivity does not come from the actual principle of frequency conversion.

4. In 1933, nearly ten years after commercialization of the first superheterodynes, Philips, which was manufacturing excellent TRF receivers, scoffed at frequency conversion in an advertising brochure entitled "'What is the difference between a superheterodyne and a locomotive?' Answer: 'None, both of them whistle at every station.'" The following year,

THE PATENTS

Having said all this, we will now have a look at the various patents involved whose principles can be connected with the method of frequency conversion defined above. We will be aided in this by de Bellecize [1] and Hémadinquer [2].

1. MEISSNER

On the 15th of January 1913, Meissner, who was an engineer at the Gesellschaft für Drahtlose Telegraphie, filed in Germany a patent whose French translation was filed the 21st of January 1914 under the number 467,747. The claims of Meissner are interesting for several reasons. (A) Among the first, he describes the beneficial effect of regeneration in a triode circuit, as well as the oscillating function which is an extreme case of regeneration.[5] (B) He describes as well the reception of continuous waves using a local oscillator, insisting on the "reinforcement" of the signal thus obtained. (C) Then follow two paragraphs which are not entirely clear: "The interference circuit described can also be used several times in succession in such a way that the interfering oscillation produced at first can act conjointly with a second generator of oscillation to produce a current of a different frequency and thus come back to interfere again." Also: "Several relays[6] acting as generators of oscillations and each coupled to a detector circuit are used in succession to provoke effects of interference, the indicator (the telephones) being connected only to the last relay circuit to render perceptible the sounds received." Finally: "There is a notable reinforcement produced, considering that one can make the amplitude of the oscillations produced by the relays considerably greater than that of the waves coming in ."

That is all, and one must exert a great deal of good will to declare, as does de Bellecize, that in this patent "the method called later on superheterodyne is described with the greatest precision." In fact, Meissner describes primarily reception by heterodyning, about which we know that it not only renders unmodulated continuous waves audible but also that it increases by its nature the strength of the signal, the heterodyne adding its own energy.

It will be seen in any case that Meissner in no way describes the essential point of frequency conversion, that is, the possibility of amplifying at will the intermediate frequency while reducing the risk of provoking unwanted oscillations.

2. ROUND AND ALEXANDERSON

In all fairness we should call to attention the two patents which, albeit distantly, are connected to this study. H. J. Round of Marconi's Wireless Telegraph Company filed in England on the 28th of November 1913, and then in France on the first of July 1920, a patent whose French number is 518,396. Alexanderson filed in the United States on April 19, 1916, a patent which in France, will have on May 8, 1919 the number 499,212.

Philips would adopt frequency conversion in turn and would not drop it again.

5. On this point, Meissner found himself in competition with de Forest, Langmuir and Armstrong. From this came a huge trial which lasted not less that twenty years. In 1934, the Supreme Court of the United States accorded priority to de Forest.

6. It is thus that Meissner called three-electrode tubes.

These two inventors are picking up the idea of causing a local oscillator to interfere with the wave received by the antenna, while looking for a resulting inaudible frequency that will then be detected, but their intentions aim at virtually nothing more than reducing atmospherics, an idea which soon proved illusory.

3. LUCIEN LÉVY

With Lucien Lévy, we arrive at the heart of the problem. He filed two patents on frequency changing, the first number 493,660 on the 4th of August, 1917, and the second number 506,297 on the first of October, 1918.

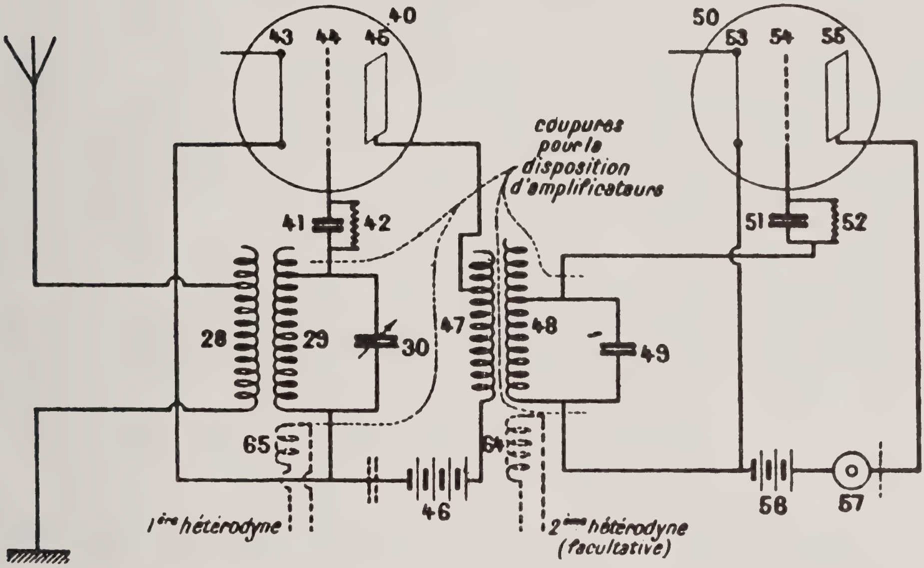


Figure 1. The first Lévy patent, No. 493,650, August 4, 1917.

Patent 493,660 covers a large domain since it begins by claiming the use "both in transmission and in reception of high-frequency currents, modulated at high frequency, the modulation frequency being itself modulated." Most of this patent covers the theme of a double modulation of transmission, and it is really only in a secondary way that he conceives of the use, in reception, of a "continuous local wave tuned in such a way as to produce high-frequency beats" with the wave received by the antenna.

Strangely, Lévy does not give much importance to the value of amplification combined with frequency changing either of the incident wave or of the intermediate oscillation. He declares in effect: "arrangements to amplify the high-frequency currents could be used interposed . . . without changing the spirit of the invention."

He sees as the value of this invention, moreover, just as did Round and Alexanderson, a means of eliminating interference and atmospherics, but prudently declares that "the selection cannot always be absolute," particularly when the interference results from damped waves.

Patent 506,297 is more explicit in that it bears this time upon a system of reception which includes:

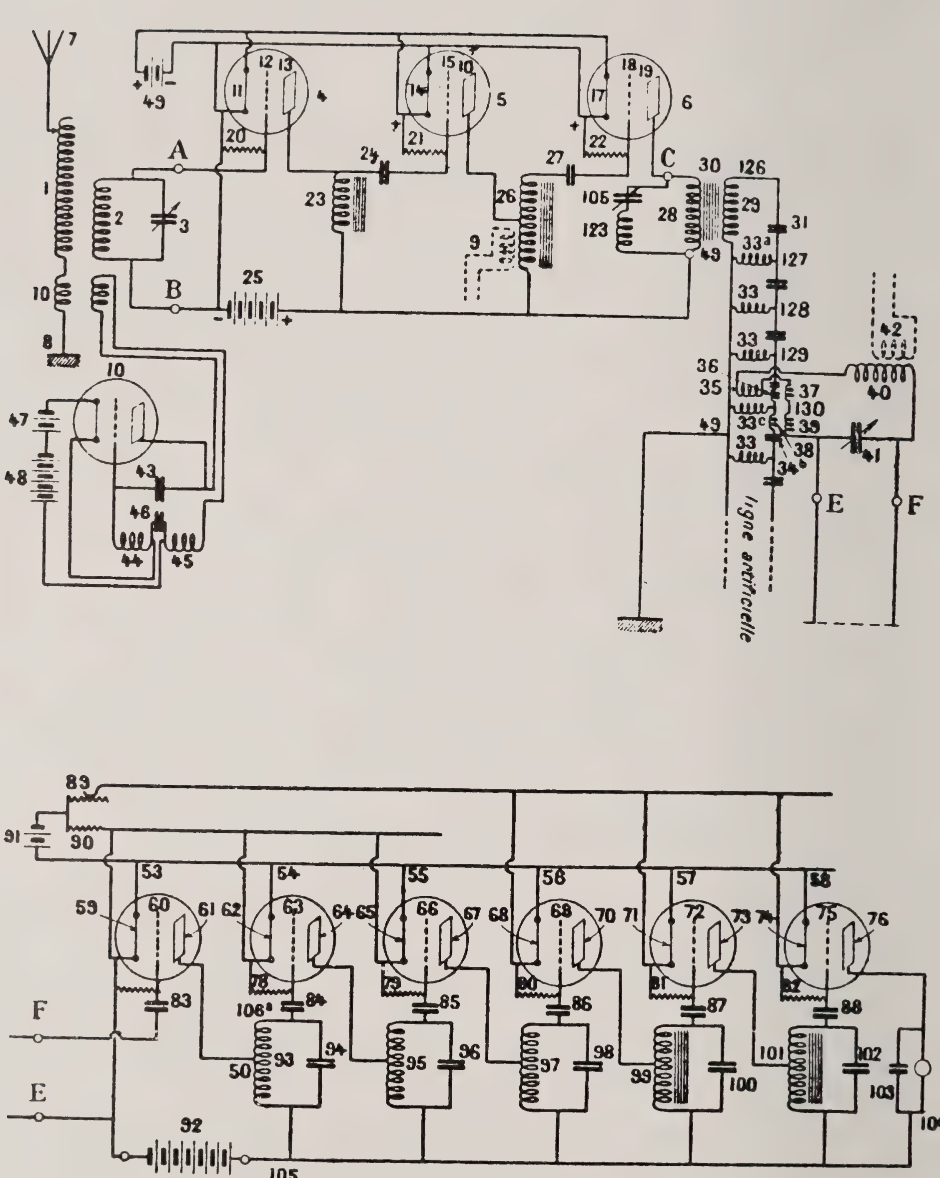


Figure 2. The second Lévy patent, No. 506, 297, October 1, 1918.

- Selector circuits and detectors tuned to the wave to be received;
- A local generator coupled to these circuits and causing with the wave received "ultra-acoustic (above audible frequency) beats";
- Selector circuits and detectors tuned to this ultra-acoustic frequency.

Contrary to his predecessors and to his first patent, Lévy insists in his second patent on the value of amplifying this intermediate frequency. Moreover, his patent is illustrated with a schematic which is precisely the one which was to be adopted later in superheterodynes. On the other hand, as he had done in his first patent, Lévy sees as the principal value of his invention only the question of an "anti-static, high-selectivity reception system." The very great potential sensitivity of his system does not seem to attract his attention.

4. EDWIN H. ARMSTRONG

For the Americans, the inventor of the superheterodyne is E. H. Armstrong (perhaps because of nothing more than the fact that he made up the name). Nevertheless the first patent taken by Armstrong on this subject is a French patent number 501,518 filed on the 30th of December 1918, three months after the second Lévy patent. There never was, as far as we know, any prior American patent. We shall why see later on.

Armstrong claims "a method of reception of high-frequency oscillations of short wave-length and especially waves inferior to 10 meters in length, characterized by the fact that the incoming energy is joined by oscillations produced locally and that the combination is converted . . . to produce oscillations of a third high frequency which are then amplified . . ."

This is definitely the principal of frequency conversion which Armstrong is rediscovering, without bringing in any new element, and even then with the restriction of reserving its use to very short waves.

5. PAUL LAÜT

Although chronologically speaking it was written on February first, 1917, thus before the first patent of Lucien Lévy, we have kept for the end the study of the note that Laüt sent on that date to Colonel Ferrié, since it was never the object of a patent.

The receiver that he describes includes an oscillating circuit coupled to the antenna and connected to a detector tube. In addition, a heterodyne is also coupled to this oscillating circuit. The beat produced is amplified by a resistance-coupled amplifier, then "rectified" again. Laüt explains: "the frequency of the heterodyne is chosen so that the beat frequency has a rather large value (10,000 to 15,000 cycles per second). Thus one can have in the telephones, after rectification by the last tube, a current curve of audio frequency having the same form as the curve of the amplitude of the voltage of the oscillations received."

Finally, he notes two essential points. First: "One can set up in cascade any number of tubes and obtain an amplification as large as desired." Second: "The advantage of this arrangement is the presence of a frequency F (intermediate) independent of that of the oscillations being received; only the tuning of the heterodyne is variable."

Can we attempt a first conclusion?

Meissner certainly invented - with others - the oscillating function of the triode,

reception by heterodyne, and the use of regeneration. It is certain that the seed of the procedure later known as "superheterodyne" is rooted in all of that, but it is not fundamentally claimed nor is it obvious. Round and Alexanderson will go a bit further, since they speak of an inaudible "intermediate" frequency which will then be detected, but their arrangements only aim at eliminating atmospherics.

Laüt is the first to systematize frequency conversion whose advantages he seizes immediately: possibility of an amplification "as large as desired" and simplicity of tuning. but Laüt is only using a resistance amplifier. Lévy picks up these ideas, but meanwhile the tuned amplifier had been invented by the military telegraph [organization] (he had a hand in that, moreover). Lévy understands its value and adopts it, thus giving the superheterodyne its definitive form.

Armstrong finally reinvents the principle of the superheterodyne, chronologically after Laüt and Lévy, and he seems to be only interested in its value as a method of receiving short waves.

Who, then, invented the superheterodyne?

THE PROCESSES

However it may turn out, we shall see that Lévy claimed to be the first and the only inventor of the system of reception by frequency conversion - that his rival Armstrong had besides baptized "superheterodyne," and that out of this arose a sharp conflict between these two engineers on the subject of priority in this invention.

But this discussion remained courteous despite its bitterness. It was not the same as that which opposed, in 1925 and 1926, in the columns of the weekly wireless review *L'Antenne*, Lucien Lévy with the partisans of the "radiomodulateur Ducretet." What was the subject of this dispute? In both cases it was a method of reception by frequency conversion, but obtained by differing means.

1) The process of Lucien Lévy consisted of using two triodes, one functioning as an oscillator and producing a local signal; the other serving as a mixer, the two signals (the incoming and the local) being applied to the grid. The intermediate frequency was picked up in the plate circuit. Lévy expressly claimed that this triode was to be hooked up as a detector (in fact, a grid-leak detector).

2) The method used in the radiomodulateur Ducretet replaced Lévy's two triodes with a bigrille (double-grid tube)[7]. The method had been invented by the Englishman Scott-Taggart[8] but was worked out in France by Jean de la Mare and René Barthélemy. The first grid of the tetrode constituted, with the plate, an oscillating triode which furnished the local signal, while the incoming wave was applied to the second grid. The intermediate frequency was picked up in the plate circuit.

Lévy filed a suit for infringement against the Ducretet company, stating that their double-grid system was not different from his triode method; in both cases, it was necessary that detection take place at the moment of mixing of the signals to cause the appearance of the intermediate frequency, or, in other words, that

7. The double-grid tube was invented and patented by Langmuir in 1913. The French patent bears the number 514,766. It was made and sold in France by "la Radiotechnique." See the article by H. Nozières and P. Giroud [4].

8. English patent 153,681. The Ducretet Company had bought this patent.

the two oscillations that were to beat with one another must act on a non-linear curve. His adversaries maintained that the use of a double-grid tube dispensed with the requirement for detection postulated by Lévy. Lévy retorted that there was indeed detection in the double-grid tube, but through the curve of the plate characteristic[9].

The author of these lines tried to learn how this judicial contest finally ended. According to Mr. Francois de Gournay, who was at the time the managing director of Ducretet, it would seem that some bargain was struck, but we have not been able to discover its terms.

PART TWO - THE MEN

1. THE *ANTENNE* AFFAIR

The end of 1925 saw the beginning of a dispute between Lucien Lévy and several wireless personalities, an argument that one might say, at the least, was not infused with the basic courtesies. It was through the intermediary of *L'Antenne*, very much followed by "wireless adepts," that the words that we are about to read were exchanged.

It all began on November 3, 1925 in number 136 by a rather mild article signed "Commander Hourst" who told of having traced out the schematic of a radiomodulateur Ducretet with a double-grid tube, and having observed that the incoming wave was applied to the first grid while the local oscillation was obtained by a coupling between the second grid and the plate. The intermediate frequency was picked up in the plate circuit.

Hourst put this diagram next to that of a superheterodyne (Lévy's) which used two different tubes to fill the same roles of local oscillator and detector-mixer, while emphasizing the fact that the double-grid tube system did very well without the first detection claimed essential by Lévy.

Up to that point, there were no surprises. It was only a scientific discussion which normally ought to have remained within the limits of the acceptable. But be patient, things will grow worse.

---

9. Lévy's idea was correct, but he and his adversaries used, with "detection," an improper term: here it is not really detection which we are talking about, a word which is reserved for the extraction of a signal at audio frequency modulating a radio-frequency signal, but really of a modulation of one signal by another, as happens in a radio-telephone transmitter, where no one would think of talking about detection when speaking of the modulation of the radio frequency by the audio frequency.

The confusion comes from the fact that, whether we are referring to modulation or detection, in both cases the signals in question must act on a non-linear characteristic: in the case of detection, to extract the audio signal from the carrier; in the case of modulation, to obtain the variations of amplitude in the radio-frequency oscillation at the rhythm of the audio signal.

In the case of the frequency changer, it is really a modulation of one signal by another that we have, for the purpose of engendering beats. It is therefore necessary that the characteristics of the tube used as a mixer (triode or double-grid) be nonlinear. If they were linear, the modulation would change the point of instantaneous functioning, without changing at all the amplitude of the signal to be modulated. We have to believe that this idea, which seems so obvious to us now, was not so at the time, judging by the lively discussion that we will quote later on.

On November 25th, 1925, in number 139, Lévy takes fire: he recalls that he had brought suit for infringement against Ducretet, and he adds that, whatever Commander Hourst may think, there is most certainly detection in the double-grid system: had Mr. Hourst never heard of plate detection? Thereupon, Lévy takes a jab at the Ducretet Company, which, he maintains, "never misses an occasion to inspire articles intended to bring confusion to technical questions of the simplest kind, but of a nature to be difficult to work out on a commercial level." This aroused the ire of Commander Hourst, who, in number 140 of the 1st of December 1925, feels that Mr. Lévy has unexpectedly "spit in his face" and that he has "told a lie multiplied by slander."

Getting back to the technical aspects, Hourst declares that the principle of the superheterodyne is found in the Meissner patent "prior by several years to all the Lévy patents," and which moreover are "property of the nation by application of one of the articles of the Treaty of Versailles."

In the same number, François de Gournay, managing director of the Ducretet Company, protests in his turn against the insinuations of Lévy, which he attributes "to the commercial success of the double-grid radiomodulateur sets."

Everything could have ended there but in number 142 of the 16th of December 1925, Lucien Lévy repeats that the radiomodulateur is nothing other than a superheterodyne. Such was not the opinion of Hourst who, in number 144 of the 29th of December, declares war while brandishing the Meissner patent and the work of Round and Alexanderson, all of which, he claimed, was prior to Lévy.

As we shall see, the new year does not see the abatement of passions. A newcomer, René Barthélemy, throws himself into the fray. Barthelemy, who was to become famous a few years later for his work in television, was an engineer for the Compagnie des Compteurs. In number 145 of the 6th of January 1926, he tries to establish a distinction between frequency conversion by addition (the Lévy system) and frequency conversion by modulation (the Ducretet system), the latter, according to him, not involving "anything like detection."

We have seen above that this opinion of Barthélemy's was erroneous. However, he throws a large rock into the pond . . . of Lévy, while avoiding naming him: "in answer to those who ceaselessly call themselves inventors of the method of frequency conversion, I feel it is my duty to shed some light upon the role of an engineer of great merit who is too often forgotten: that of Mr. Laüt. Mr. Laüt was assigned to the Radiotélégraphie Militaire, but was sick and undergoing treatment at Berck in 1916, at which time he proposed, by letters to General Ferrié, the system that Armstrong later named the superheterodyne."

In this number of *L' Antenne*, Lucien Lévy answered the preceding statement of Commander Hourst. Obviously he denies that his patents are plagiarized from Meissner, Round and Alexanderson, and he counter-attacks by opposing to the Ducretet radiomodulateur a circuit of a frequency changer using a double-grid tube that, seven months before the filing of the Ducretet patent, was apparently described by two engineers of "La Radiotechnique," H. Nozières and P. Giroud, during a meeting of the Society of the Friends of Wireless.

Lévy felt that under these conditions, speaking of the radiomodulateur Ducretet as involving new theory . . . could only provoke a most justified outburst

of laughter among the readers of *L'Antenne*[10].

In the following number (146 of the 12th of January 1926), Commander Hourst states that as far as he is concerned, the discussion is over. Exit Commander Hourst, not without having shot one last barb at Lévy: " . . . it appeared during the discussion that the function of the superheterodyne was fathered by many men and we find each day a new name to add to the list (see the article of Mr. Barthélemy in the last number of *L'Antenne* on the subject of Mr. Laüt)."

In number 147 of the 19th of January 1926, Lévy takes the challenge. After having given Mr. Barthélemy a lesson in applied mathematics and having accused him of "superficiality," he challenges him to prove his assertions on the hypothetical priority of Mr. Laüt.

Barthélemy replies in number 148 of the 26th of January, that he is ready to remit to the magazine the "Laüt document." Then he launches himself (in Nos. 149 and 150) into a rather murky discussion which tries to prove to Lévy that the latter has misinterpreted his mathematical reasoning on the frequency changer.

In the same number 150, Lévy replies to some earlier technical notes of Barthélemy, stating that the latter has not understood any of his (Lévy's) ideas.

Sixty years later, what comes out of this rather trifling discussion for an impartial reader is that we are dealing with two engineers of equal merit who are fundamentally of the same opinion, but who, cordially detesting each other, wish to show:

- That the other is grossly mistaken on the theoretical level, which brings into question his professional qualities;
- That, moreover, he is mistaken (or pretends to be mistaken) on the ideas of his adversary, which brings into question his good faith.

Major wars have been declared for far less. Nevertheless, in number 151 of the 13th of February 1926, Lévy starts in again. He publishes a diagram which appeared in June 1924 in the English magazine *Experimental Wireless* under the signature of A. L. Williams and entitled "Superheterodyne Receiver with Six Tubes with a Four-Electrode Tube." It is obviously the same principle as the radiomodulateur Ducretet, which allows Lévy to state that "the radiomodulateur is not new. It is not due to Mr. de la Mare or the Ducretet Company. It was described in detail in a publication seven months before the filing of the Ducretet patent and designated by its author as the superheterodyne."

Thereupon, six weeks pass and one might believe that the affair had finally been laid to rest, but on the 28th of March 1926 (number 157) it bounces back even harder. This time, it's the editor of *L'Antenne*, Henri Etienne, who adds to the fire by publishing the notes sent on the first of February 1917 by Laüt to Ferrié, notes of which we have already spoken in the beginning of this study, in the paragraph consecrated to patents and priorities. These notes, according to Etienne, were sent by former colleagues of Laüt at the Eiffel Tower station.

---

10. Lévy wanted to be right at all costs. If he had read more carefully the communication of H. Nozières and P. Giroud which we have already mentioned [4], he would have realized that these authors were not at all presenting a frequency conversion circuit, but simply a regenerative detector which had the advantage, thanks to the use of a double-grid tube, of working with a very low plate voltage.

Etienne doesn't mince words: "The notes mentioned contain the essential part of the later claims of Mr. Lévy, then assigned to the Eiffel Tower station . . . he (Laüt) indicated to the researchers a circuit allowing through double rectification preceded and followed by amplification the reception of short waves, and did it long before Armstrong and Lévy."

Lucien Lévy answers in the following number (159 of the fourth of April 1926), and one has to believe that he is somewhat embarrassed, judging by the specious arguments that he presents. He contests that Laüt was indeed an engineer at the Eiffel Tower on the date of his note, February 1st, 1917, indicating in fact that "he had been sick for months out in the provinces and sent by letter the result of his meditations to General Ferrié and to Commander Brénot, who is now chief executive of the Société Française Radioélectrique." He states that it was in August 1917 that he (Lévy) was given the authorization to take out certain patents for "certain inventions that I had conceived a long time before." Captain Brénot had, he said, forwarded his application with a most positive recommendation and had added: "The work in question is absolutely personal. No attempt has been made at verification on the practical level, but the arrangements suggested are

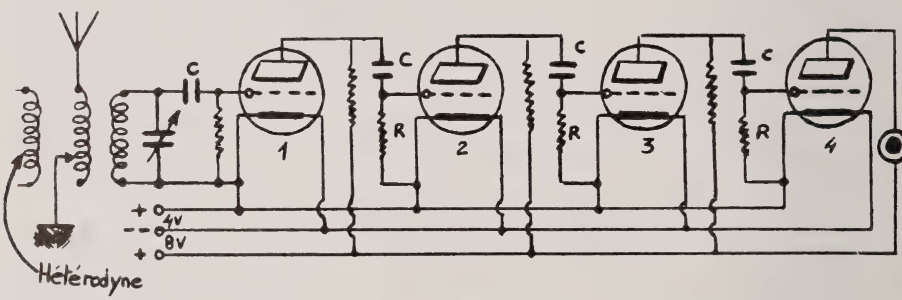


Figure 3. The diagram accompanying Laüt's note of February 1, 1917 (after *L'Antenne*, no. 157).

very interesting and may have some very important applications. It would be well to test them out as soon as possible."

And Lévy comments: "It certainly seems to me that at this moment, the 'remarkable' little note of Mr. Laüt had not attracted a great deal of attention." He adds that in October 1918, he had published on his own system of reception a note to which Ferrié had added an annotation: "The studies of the process which have just been briefly described have been in progress for about two years. October 15th, 1918," signed "Ferrié."

Technically speaking, Lévy criticizes the diagram accompanying Laüt's note, in particular the fact that he uses a resistance amplifier, which causes the loss of all the advantages of selectivity of the superheterodyne. Lévy ends by stating that "The little note of Mr. Laüt brings no moral proof at all of the priority of his invention" and he further states that "wireless in France has still a great deal to do to escape from the tyrannical imperialism which, in the wings, prepares its somber machinations [sic]."

The argument will continue for several weeks more. In the following numbers of *L' Antenne*, articles on the subject will be entitled: "on Mr. Lévy and secon-

darily on frequency conversion." Etienne gives us to understand that, more than the technical aspects of the problem, it is the personal behavior of Mr. Lévy which is in question.

In number 159 of the 11th of April 1926, Etienne launches a direct attack on Lévy and mounts an energetic defense of Mr. Laüt, and that, it must be said, in a rather hypocritical way: Etienne pretends to believe that Lévy had criticized Laüt for having been sick at the time of his famous notes. He deems "scandalous and unworthy" the manner in which Lévy spoke of the "meditations" of Laüt, whereas it was really a "work completed for its own reward." "That alone, Mr. Lévy, just these words, this little sentence lowers you in my esteem" and further on: "Have I ever reproached you for lining your pockets?"

The tone is obvious. And to top it all off, Etienne will use the same occasion to attack someone who seems to surpass even Lévy in his execration: "Don't imitate Marius Latour[11], believe me, you would cover yourself with ridicule. That seat is taken."

It is now that Mr. Brénot puts in his oar, in number 160 of the 18th of April 1926. Let us recall that Brénot was director of the military station of the Eiffel Tower during the war, with the rank of Commander. Then he became director of the Société Française Radioélectrique, with the title of colonel in the reserves. Brénot steers quite clear of having wished, by annotating Lévy's patent, to grant any sort of priority to the invention outlined in the application (the superheterodyne). He willingly recognizes that the note of Laüt, distributed among the technicians at the Eiffel Tower seven months before the patent application in question, did not hold his attention for, as he says, if this idea of Laüt's became later on important, it really had no application to military telegraphy. As for the work of Lévy, it was presented as aiming for the elimination of static, and it was from this point of view that Brénot had appraised it.

We will have to shorten this discussion, for the distinction is becoming mired in personal considerations between Lévy and Etienne, which have little to do with frequency conversion. Let's end up with number 162 of the second of May, 1926. Now Marius Latour, very upset with certain ironic remarks of Lévy, enumerates the inventions he claims to have fathered: the use of a common battery for all the tubes in an audio amplifier; the method of calculating the gain of such an amplifier; use of iron cores in radio-frequency transformers; combination in a single apparatus of radio-frequency and audio-frequency amplification. All these arrangements are used in Mr. Lévy's radios.

In his turn, Emile Girardeau, director of the SFR, takes Latour's defense, asking Lévy why he doesn't file suit? Lévy replies that shortly after the note of Laüt of the first of February 1917, the SFR tried to patent - following the idea of Laüt - "the use of a heterodyne for reception in wireless telephony." He deduces

---

11. Marius Latour, an engineer at the Société Française Radioélectrique, was an eminent technician but also an excellent businessman. Besides his own patents, he had bought several others of which the creators had not seen the interest, and had been able to exploit them very well. It was this way that he bought from Peri and Biguet their patent on the TM tube (with cylindrical and coaxial elements) and that he received fees from all the French manufacturers of vacuum tubes for 15 years. This savoir-faire wasn't to the taste of everyone.

from this that the SFR's whole interest here is to deny to him, Lévy, the invention of the superheterodyne because of "the money which the commercial exploitation of the superheterodyne would gain for the SFR."

The last line of this long and involved discussion (which lasted no less than six months), will be written in number 165 of the 23rd of May, 1926 in three open letters addressed respectively to the magazine by Latour, Girardeau and Barthélemy, in which each of these will rehash without adding anything new, the arguments already brought to bear against Lévy.

2. LÉVY AGAINST ARMSTRONG

It remains for us to discuss the dispute which arose about the same time (1926) between Lucien Lévy and Edwin H. Armstrong. The latter was then a professor at Columbia University in New York, but at the time he had developed his superheterodyne in 1917-1918, he was a major in the U. S. Signal Corps and was in Paris where the Americans had set up a laboratory which was working in liaison with the Military Telegraphy organization.

In his 1926 book The Superheterodyne and Superregeneration, P. Hémard-

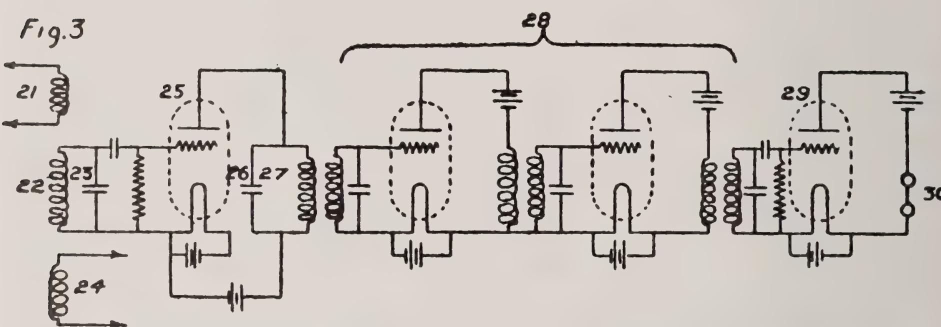


Figure 4. One of the circuits in Armstrong's French patent No. 501,511 of December 30, 1918.

inquer published the respective arguments of Armstrong and Lévy. The text of Armstrong was reproduced from an article which had appeared two years earlier in the *Proceedings of the IRE* [7].

As strange as it may seem, Armstrong announces in the opening lines of his paper that "the invention of the superheterodyne goes back to the early months of 1918." On the other hand, he seems entirely unaware of the work of Lévy: his name is never mentioned. However, it is difficult to believe that by 1926 Armstrong would be unaware that the first patent by Lévy dated from August 1917.

Armstrong details the following points. When, in 1917, the Americans entered the war, the American Expeditionary Force had to resolve the problem of receiving damped waves of frequencies going from 500,000 to 3,000,000 cycles[12], with the fewest possible tuning adjustments. Now, the tubes made in the United States at this time had internal capacities that were much too high for this work.

---

12. It could in no way be a question of receivers to be used by troops in the field, since continental and transcontinental communications were, as everyone knows, carried on in continuous waves of kilometric length.

At the beginning, the problem was solved "thanks to the good will and energy of General Ferrié and his staff"; but it could only have been a temporary solution, and it is then that Armstrong thought of changing the frequency through a heterodyne and of amplifying this intermediate frequency. There follow long considerations by Armstrong on the advantages of the superheterodyne and its commercial success, which we will not dwell upon.

Before moving to Lévy's response, we will cite the work of Armstrong's biographer L. Lessing [6] on the work of Armstrong. During an air-raid alert in the beginning of 1918, Armstrong, who was watching the raid from one of the bridges over the Seine and who noticed the poor efficacity of the anti-aircraft fire, wondered if it would not be possible to detect airplanes by receiving the weak electric oscillations emitted by their ignition systems. He estimated the frequency involved at "more than 10,000,000 cycles" but there existed at the time no receiver sensitive enough for such frequencies. It was then that he is supposed to have had the idea of frequency conversion. He filed a French patent on the 30th of December 1918, then an American patent on the 8th of February 1919, which was granted on the 8th of June 1920 under the number 1,342,885.

Lessing goes on to say that Armstrong received in February 1919 the ribbon of Knight of the Legion of Honor. Further on, he mentions the differences which arose between Armstrong and several inventors who allegedly had imagined systems "vaguely" recalling that of Armstrong. "The most surprising of these claims" was that of Lieutenant Lucien Lévy whom Armstrong had met a few times in France and whose system was virtually unusable, and which brought no solution to the problem of detecting weak enemy signals. Besides, Lessing adds, one cannot judge the claims of Lévy concerning the superheterodyne because of the fact that the French government recompensed Armstrong for his invention but never accepted the claims of Lévy[13].

There is how history is written.

Let us get back to the book by Hémadinquer (2) written in 1926. Lévy answers the note by Armstrong. But the more Armstrong evinces calm detachment, the more Lévy is aggressive, as if on the defensive . . . from attacks that he has not yet had to face. Right out of the gate, Lévy speaks of the series of inexactitudes that Armstrong's exposé is supposed to include. He says that he first got the idea of frequency conversion in June, 1916; that in 1917, Armstrong was chief of the American research service in France, and that it was for this reason that as soon as Lévy took out his patent of the first of August 1917, he must have learned of it, the French services having communicated it to the various allied services.

"We should not, therefore, be surprised," concludes Lévy, "at the coincidence between the ideas of Armstrong and those of Lévy." This is a rather pointed re-

---

13. Armstrong had a tragic end. The three inventions of which he was the most proud - the oscillating function of the triode, the superheterodyne, and frequency modulation - were bitterly contested: the oscillating triode by de Forest and a few others; the superheterodyne by Lévy and others; FM by RCA. He lost most of his trials (he never had one with Lévy). Beaten by these failures, ruined financially, and in spite of the backing of all the great American scientific associations who had given him prizes and medals, he could not overcome his disappointments and took his own life in 1954.

mark by Lévy when one considers that it is likely that he himself was inspired by a certain note written by Laüt . . .

3. AN AUTHORIZED OPINION

We shall end this study by citing the opinion of the eminent German physicist Walter Schottky, to whom the early days of radioelectricity owe many discoveries. In October 1924, Schottky published in the *Proceedings of the IRE* [5] a short study of the origin of the superheterodyne. He states that in the end of 1917, the Siemens laboratory that he was in charge of had, like Lévy, worked on the problem of frequency conversion. Voluntarily or not, Schottky leaves room for doubt on the manner in which he had become aware of the value of the system. Is it by chance that he had undertaken this study three months after the application for the first patent was filed by Lévy (that of the 4th of August 1917)? Or did he already have knowledge of it (but how, since it was wartime?) and had he recognized its value? Both interpretations are possible. In any case, to add to the confusion, Schottky declares that Lévy had apparently already patented his invention in England on the 8th of April 1917 under the number 143,583. This point would be worth verifying.

Schottky sweeps away in this area the priorities of his compatriot Meissner and those of the Englishman Round. He keeps only the merits of the Lévy patent and the Armstrong patent. Of the first, he says that it is of "fundamental importance," and that we must consider Lévy as the true creator (originator) of the superheterodyne system. On the other hand, he accords to Lévy only the merit for the idea (the word), to give to Armstrong the advantage in the area of practical realizations (the deed).

On the date when Schottky wrote *that*, it was still true, since it wasn't until the same year 1924 that Lévy brought out his first commercial superheterodynes, while Armstrong [via RCA] had already done so in the U. S. two years before. But it is only right to recall that the superheterodynes made by the firm of Lévy (Radio L. L.) will know for fifteen years a well-earned commercial success, without mentioning the fact that frequency conversion will later on become virtually unique as the procedure for receiving Hertzian waves.

CONCLUSIONS

One can, without risking much error, thus describe the paths of thought which led to reception by frequency conversion.

At the beginning of the First World War, the idea of causing the incident wave to beat with a local oscillator and to amplify the resulting inaudible frequency was "in the air." However, Round and Alexanderson saw only the (debatable) value of reducing static. It was in fact Laüt - who had probably never seen their work - who thought of making frequency conversion a systematic method of reception of great sensitivity, and brought out a few of the most substantial advantages.

But Laüt was not able - and for good reason - to carry to the end by trying out his proposal. That Lévy knew of the note from Laüt is highly likely, and he would have brought honor to himself by recognizing it. At least he had the merit to use a tuned amplifier after his frequency changer and especially to develop

theoretically and experimentally this method, to the point of rendering it convenient to use and commercially viable.

As for Armstrong, in any case his patent is posterior to that of Lévy. We must give him credit for having carried out in the U. S. a work of development and of perfection similar to that of Lévy in France.

It is the same with the invention of the superheterodyne as with that, more general, of the invention of wireless telegraphy: if it is difficult to designate a unique inventor, one can at least say that there was a "main person responsible," the one who took on the unpleasant work of making an idea go from the almost fairy-land domain of theory to the much more down-to-earth domain of practise and realization. These "main persons responsible," we believe, are Marconi for wireless, and Lévy and Armstrong for the superheterodyne.

REFERENCES (French titles translated)

1. de Bellecize, The Superheterodyne, Principles, Evolution, Editions Chiron, 1926.

2. P. Hémadinquer, The Superheterodyne and Superregeneration, Editions Chiron, 1926.

3. R. Champeix, "Lee de Forest and the Invention of the Triode," *Le Vide*, No. 128, March-April 1967.

4. H. Nozières and P. Giroud, "The Four-Electrode Tube," *The Electric Wave*, December 1924.

5. W. Schottky: "The Origin of the Superheterodyne," *Proceedings of the IRE*, Vol. 14, No. 5, Oct. 1926, pp. 695-698.

6. L. Lessing, Man of High Fidelity: E. H. Armstrong (New York: Bantam Books, 1969).

7. E. H. Armstrong, "The Super-heterodyne - Its Origin, Development, and Some Recent Improvements," *Proceedings of the IRE*, Vol. 12, No. 5, Oct. 1924, pp. 539-552.

Robert Champeix

Born Jan. 5th, 1911. Doctorate in engineering. Twenty-five years with Philips, specializing in the research and development of electronic tubes; ten years with CSF in the same specialty. Ten years as consulting engineer and expert for the courts, at the same time working as a professor of electronic physics. Publications: two works on the development and manufacture of electronic tubes, translated into Russian; 12 papers presented to the Academy of Sciences; 25 diverse articles; 8 patents. Honors: twice a laureate of the Academy of Sciences; holder of "Les Palmes Academiques"; silver medal of Transmissions.

AMATEUR RADIO IN THE NEW YORK CITY AREA PRE-WW I

Daniel C. McCoy, W8DG

[Reprinted from AWA Old Timer's Bulletin, Vol. 2, No. 3, 1961. Originally designated AWA Monograph No. 1.]

My entry into amateur radio began about 1901. My father brought home a book on electricity which my curiosity caused me to explore. I came upon a chapter devoted to "wireless." This intrigued me and it was not long until I started trying to duplicate the equipment shown, namely, spark coils, coherers, etc. There was no school near home in Yonkers at that time, so I went through my first few grades at Tarrytown, New York, living with my grandfather, who was Superintendent of the Hudson Division of the New York Central Railroad. He had a railroad telegraph line into his den at home and most every evening he would "listen in on the wire." He taught me the American Morse code; getting a key, batteries and a sounder so we could practice. Thus, the usual chain of progress for amateurs was reversed: when I did hear my first "wireless" signals I could read some of them and identify the stations, adding to my thrill and enjoyment of the hobby.

My first two-way contact was in 1906 with Irving Vermilya, call letters "VN" at that time, living in Mt. Vernon, perhaps 10 or so miles away "as the crow flies." Today, I still work Irving occasionally as W1ZE.

American Morse code was used by all U. S. commercial, government, and amateur stations except the Marconi Company's ships and shore stations. It was not until after the Titanic disaster, April 15, 1912, that serious consideration was given to adopting an international code for wireless work. The Continental Morse code was finally adopted and today is the recognized code for radio operation. Many squabbles ensued between proponents of the two codes before this came to pass. Our U. S. radiomen were better off as many of them had to work landlines at shore stations, and knowing both codes added to their versatility. It is interesting to read some of the arguments in the old literature. My personal opinion is that the American Morse code is faster, and no more susceptible to errors due to static and QRM. I still use it on the air with many of my old boyhood buddies, and some old landline telegraphers who have adopted amateur radio as their hobby. Most American Morse men, especially the old-timers, have a distinctive "fist" and send cleaner, better spaced and more easily read CW.

Wireless equipment in the early days was decidedly crude. For some years there was no "store-boughten" equipment and you had to "roll your own." Finally, the Electro Importing Co. in New York City came into existence, followed by wireless gear from the Manhattan Electrical Supply Co. under the able direction of Lou Pacent, then J. H. Bunnell and other sources. Nevertheless, most amateurs in those days built their own, primarily for financial reasons but also for the pure joy of accomplishment.

As to the financial side, I might comment that in those days I was delighted to get an occasional job mowing a lawn of goodly size with a hand-mower for a

quarter. Today I pay a high-school boy with a "ride around" power mower $7.50 per cutting to manicure my lawn! He has a regular clientele which keeps him busy every day during summer vacation. At least he is willing to work. So no wonder most of today's newcomers go down to the radio store and buy their equipment instead of building it.

Outside of signals picked up across the room from a small spark coil as transmitter I was never able to get any results with a coherer. My first successful receiving equipment used a single-slide tuner, a "microphone" detector and a 75-ohm earphone, with a whale of a big antenna. With this I was able to hear ships in New York Harbor, several of the nearby shore stations, and the Fall River Line steamers when they were on Long Island Sound. Maximum range not more than perhaps 50 miles.

Commercial stations heard in and around the New York City area in the early days were:

AX	United Wireless Co., Atlantic City, NJ
BD*	Massie Wireless Co., Jerome Ave., Bronx, NY
BG	United Wireless Co., Bridgeport, CT
BS	United Wireless Co., Bellevue-Stratford Hotel, Philadelphia, PA
CC*	Marconi Wireless Co., South Wellfleet, MA (overseas press)
DF*	United Wireless Co., Manhattan Beach, NY
HA	United Wireless Co., Cape Hatteras, NC
MSE*	Marconi Wireless Co., Sea Gate, NY
MSK	Marconi Wireless Co., Sagaponack, NY
NAG*	U. S. Navy, Fire Island, NY
NAH*	U. S. Navy, Brooklyn Navy Yard, NY
NY*	United Wireless Co., 42 Broadway, NYC
OHX*	New York Herald, Battery Park, NYC
WA*	United Wireless Co., Waldorf-Astoria Hotel, NYC
WN	Massie Wireless Co., Wilson's Point, CT

Some, of course, have been forgotten, but prior to 1908-09 those marked * were old reliables and were depended upon to test receivers and for listening pleasure. For me, DF and the Fall River Line steamers at about 5:30 to 6:30 PM when they were due east of me in Long Island Sound, were my first stations heard and most reliable. From 1909 on practically all of them could be heard at night. Of course, ships coming in and going out of New York Harbor were heard quite often.

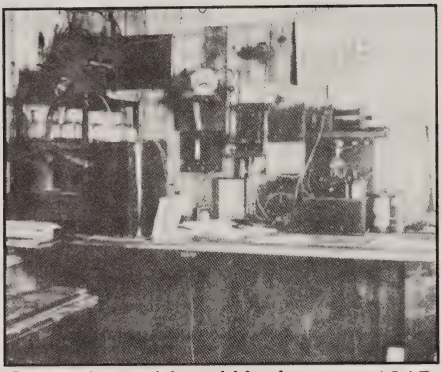
The microphone detector consisted of two pieces of carbon taken from a dead No. 6 dry cell, each sharpened to a needle point. The sharp ends were mounted far enough apart so that a sewing needle could be laid across the two pointed carbons with a thread and fishline sinker tied to the middle of the needle to hold it in position and give some pressure to the contact between the needle surface and the surfaces of the carbon. The slightest jar would knock it out of adjustment so that you hardly dared to breathe on it when you were receiving signals. The one-slide tuner was not a marvel of selectivity. Often several stations could be heard at once - yes, we had QRM in those days. However, wavelengths (today's frequencies) were not standardized and you usually had to "fish around" to find signals. More on this wavelength business later.

Electrolytic detectors using Wollaston wire were the next advance. This wire consisted of a very fine inner core of platinum wire covered by a heavy layer of silver plate. The silver plating at the tip of the wire was dissolved off and the very fine platinum wire dipped into a solution of nitric acid held in a hole in a piece of carbon. These detectors were very sensitive by the standards of those days and brought in good signals when adjusted properly. A small voltage had to be applied in the right direction across them, requiring a potentiometer which most of the boys would wind on a piece of broomstick using insulated wire, then scrape the insulation off on one side of the wire and run a slider along it to get the correct voltage adjustment. Dry cells shunted across the ends of the winding supplied the voltage to the potentiometer.

Following the open type of electrolytic above, a more stable but less sensitive type, the sealed electrolytic, was obtained by sealing the Wollaston wire into a glass tube with one end immersed in the acid. Neither type would stand radio energy from the local transmitter. The platinum wire would burn off, requiring reforming and readjustment after each transmission. These were soon abandoned in favor of crystal detectors.

Most of these consisted of a piece of silicon, galena, or pyrites, upon the surface of which a very fine "catwhisker" of wire made contact. Pressure of the contact, and location of a sensitive spot on the crystal surface were essentials for adjustment. These detectors were also sensitive to shock and jarring and to energy from the transmitter. More often than not, they had to be readjusted after each transmission. These were followed by the "Perikon" consisting of a crystal of iron pyrite in contact with a piece of red zinc oxide, and the silicon-antimony with a small bit of antimony metal in contact with a piece of silicon. These crystals were set in cups of Wood's metal. Here again, hunting around for the sensitive spot was the first requirement of good adjustment, but both required a mild pressure between the two elements and were not as subject to shock or jarring as the catwhisker types. The Perikon was the more sensitive of the two: however, it was no better from the standpoint of being knocked out by the transmitter, whereas the silicon-antimony stood this very well and was in my opinion the most satisfactory overall detector of its time. The carborundum detector, which became extensively used by the old United Wireless Co. and the American Marconi Co., consisted of a piece of carborundum, sometimes set in a cup of Wood's metal, with a blunt point against the carborundum with substantial pressure applied. This was not as sensitive as the Perikon, silicon-antimony or some of the catwhisker types, but would stand an awful lot of shock and jarring, would take energy from the transmitter and stay in adjustment. In fact, some of the commercial stations used break-in with carborundum detectors, by placing an "anchor gap" in the ground lead from the transmitter as near to ground as possible and connecting the receiver across the gap. I used this at old 2HA for some time. The carborundum detector, for maximum sensitivity, also required a small voltage across it like the electrolytic.

Finally came the Audion, the predecessor of present-day vacuum tubes. When first brought out, these were out of reach financially for the run-of-the-mill amateur, through the usual sources of supply. However, it soon became known that rejects could be obtained from the manufacturer (through the back door) for a five-spot, and many amateurs soon adopted the Audion and discarded the crystal



Operating table, 2HA, January 1915. Receiving equipment on right. Antenna switch to left of receiver, replica of United Wireless switch. "Anchor gap" above, replica of United Wireless gap. Tuner, modified Murdock loose coupler (slider on primary replaced with tap switch); de Forest Audion detector with B-batteries in box beneath Audion cabinet; filament batteries, No. 6 dry cells to right, filament rheostat knob on left of Audion cabinet; secondary tuning condenser (Murdock) to right; plate regeneration variometer (de Forest) to left of Audion cabinet. Key breaking primary of transmitting transformer on extreme right.

detector. I sometimes wonder if the manufacturer did not do a more sizable volume through the back door by sales to amateurs than he did through regular outlets!

The Audion was extremely sensitive compared to its predecessors, and would bring in signals far better than any device so far available to the amateur. It also could be "souped up" by properly placing a permanent magnet from a telephone ringer in proper relation with the bulb of the Audion.

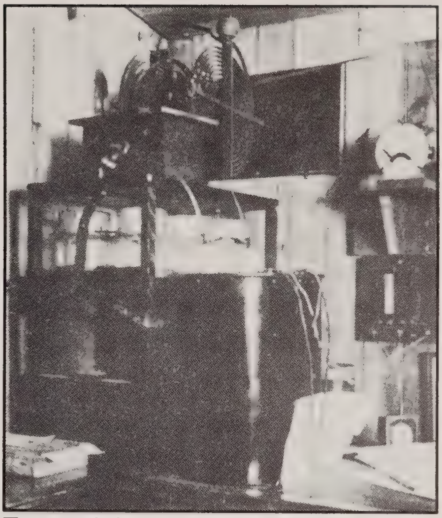
Loudspeakers were unknown in those days, headphones being the means of hearing the signals. It was quite a shock to put on the phones for the first time using an Audion detector after being accustomed to the signals received over the older types of detectors. "I'm reading you with the phones on the table" was equivalent to today's "599-plus" report!

Unlike today's tubes, the old Audions were erratic as to the plate voltage required for each tube. Some would operate on 15 or 20 volts, while others would require 100 to 200 volts. So when one acquired a "back door" tube, more likely that some experimentation with plate voltage would be necessary. Lucky was the amateur who came by a 15- to 20-volt tube and did not have to have a sizable investment in "B" batteries.

As to tuning equipment, the one-slide tuner was in time replaced with the two-slide type. Many thought two-slide tuners made it better. The old United Wireless Co. three-slide tuner was copied to some extent by hams. It required a special antenna with two lead-ins, these making a loop through the other end of the antenna. Finally about 1910 or so the loose coupler came into use and became the standard.

Following the loose coupler, tuning condensers came into use for more accurate tuning. My first tuning condenser consisted of a dead No. 6 dry cell with foil wrapped around the cardboard container on the outside forming one electrode (today's stator) and the zinc of the cell forming the other electrode (today's rotor). Of course, the cell and container had to be in a sufficient state of preservation so that the cell itself could slide in and out of the cardboard sleeve. By efficiency standards of these days it mattered little if the cardboard was rather wet from chemical absorbed from the deteriorated cell, just so long as it would slide. "Low-loss" had not yet been invented, and we did receive signals with this crude device, in fact, the first one I saw was in a commercial shore station.

For transmitting, the amateur of the early days usually started out with a small spark coil and slowly graduated to a larger one. A quarter-inch spark coil, the quarter inch being the distance the spark would jump between two electrodes of a spark gap, was common for the beginner. Later a coil from the ignition system of the old Model "T" Ford automobile became standard practice for the new ham. This coil was able to give a spark of about 1/4 to 3/8 of an inch. A two-inch spark coil was high power, and the occasional amateur who could come by a six- or eight-inch spark coil had super-power. Here I might add that the early transmitters on the British Marconi marine installations used ten-inch coils, and the first transmitters I used in 1911 on the Fall River Line steamers used about the same.



Transmitting equipment, 2HA. Top to bottom, then left to right: "pancake" tuning inductances, home-made from brass ribbon and fiber insulating strips; boxed-in spark gap; condenser, United Wireless Leyden jars; Packard 1-kW transformer, keyed in 110-volt primary; home-made hot-wire ammeter to measure antenna current, made from old alarm clock and piece of thin iron wire; kickback condensers to bypass RF picked up by AC lines to ground and protect primary from RF burnout. Note heavy ribbon RF connections.

At first, the coil was hooked up with one side of the spark gap connected to the antenna and the other to the ground. No tuning coil was used. Your frequency, or wavelength as it was termed in those days, depended mainly on the size of the antenna and the length of the ground wire. Later, tuning devices were added. However, little thought was given to measurement of wavelength. For some time you would rarely find ships or shore stations on the same tuning adjustment of your receiving equipment, and the same for amateurs. You had to "fish around" until you found them, then mark your tuner so you could find them the next time.

For example: in the summer of 1912 I was assigned to the S. S. North Land of the Eastern S. S. Lines on the New York to Portland, Maine, run. Leaving New York, we were required to report in when leaving the dock. I never had any trouble raising the New York City station NY leaving dock, but as soon as I got beyond the Brooklyn Bridge and out into Long Island Sound, I could not raise any station in or around New York to save my soul. I had no trouble raising stations around Boston or Cape Cod when near there; also ships not too far away. I felt I was not getting what I should out of my equipment. It certainly did not compare with the performance I had from equipment of the S. S. North Star the previous summer on the same run. So after worrying with this for a week or ten days, I complained. The Port Inspector (none other than Dave Sarnoff) came down to check the transmitter. To make a long story short, my transmitter was

Antenna, 2HA. 50-foot spliced mast. The one with steps is the one I rode down. It was re-erected without top mast. Antenna about 100 feet long, three wires of seven-strand No. 21 phosphor bronze, insulated with small Electrose insulators on each wire at spreaders. Spreaders about 10 feet wide; three-wire lead-in from tip of mast to shack at foot of mast. Operated against ground consisting of numerous wires buried just below surface of lawn. Antenna supported at near end from electric light pole across the street.

tuned to about 250 meters instead of 600. The antenna on the North Land was short and fed slightly off-center. After tuning the primary circuit I was in business. How many other ships and shore stations were in this same fix I do not know. Judging from the way you had to hunt for them on the tuner, I'm inclined to think it was more common than not. Next summer when I took the S. S. Old Colony on the same run, things were decidedly better. Probably "D. S.," with his usual thoroughness, had taken a lesson from the S. S. North Land, and cleaned up a lot of the stations while I was back in school during the fall, winter and spring.

The "note" emitted by most spark coils, particularly the old Marconi equipment, was a low growl. Amateur equipment gave off a variety of notes, depending on how fast the vibrator on the spark coil made and broke the primary circuit. Power for amateur transmitters came mostly from dry cells or storage batteries, the latter being the de luxe equipment of those days. Gas lighting was still widely used in houses; few were wired for electricity. In fact, our home, while wired when built, was not lighted by electricity for some years after I had AC in the shack in the back yard to operate my transmitting equipment.

Finally, alternating-current transformers came into use, replacing spark coils. Along with them came attempts to tune signals to some wavelength. The use of AC required high-voltage condensers on the secondary side of the transformer. These were a pain in the neck for all of us for some time. Most early high-voltage transmitting condensers were made from old 8" X 10" glass photographic plates with tin foil sandwiched between the plates, and the whole assembly of ten or so plates dipped in some "gunk" to seal out the moisture. These plates would puncture and the whole condenser would have to be taken apart to locate the punctured plate and replace it. Mom's kitchen stove would have to be called into service to melt out the gunk - too often with overheating and the gunk filling the house with smoke as it dripped out into the oven and fried!

My first high-power AC transmitter was bought from Randy Runyon, now W2AG, when he replaced it with a United Wireless "coffin" and associated equipment. It had a Clapp-Eastham 1-kW "resonant" transformer, and a high-

voltage condenser of back-breaking weight, dimensions about 30" X 14" X 14", filled with sections made from 8 X 10 photo plates, perhaps 15 or 20 sections. These were connected to two brass bars on the outside. As one section burned out you would disconnect it and wire in a good one. The number of sections more or less determined the pitch of your note. As I recall, about one-third of the sections in the box was about right for a good-sounding note for me. So you just kept changing sections until they were all burnt out: then you had to dismantle the whole mess and repair it. I know my mother would have liked to skin me alive more than once until I replaced the condenser "coffin" with some Leyden jars. And thereby hangs a tale.

By this time, most commercial stations used Leyden jars. These were made of glass suitable for the electrical stress that the high voltage put on them. The 8" X 10" photographic plates were never meant for electrical stresses encountered in condenser service. Instead of tin foil, the electrodes were copper plating deposited on the inside and outside of the glass. It was very rare for these to break down, particularly in amateur service. The amateur who could come into possession of enough of these to handle his high-voltage transmitting condenser needs really "had it made." I finally acquired six, and have a sneaking suspicion that the breakdown and replacement of these in commercial service was very high judging by the rapidity with which amateur use of Leyden jars increased. Molded high-voltage condensers were also introduced by Murdock and solved many amateurs' problems.

Most of the commercial operators in those days were recruited from amateur ranks. I served on my first ship, the S. S. North Star of the Eastern S. S. Lines, in the summer of 1911 when I was only 16 years old. A curve shown in a paper by C. Ford Greaves in the September 1914 *Proceedings of the Institute of Radio Engineers* shows that the majority of the First Class operators were 19 years old as of February 14, 1914, which happened to be my age of that date. Many of my amateur contemporaries were in the group. Many, like myself, worked only in summer vacations or during holidays. Some either left school for a career of radio operating, or bowed out for a while to go to sea and then went back to finish their education. Commenting on these statistics, Greaves says:

> "It is interesting to note that most of the operators are 19 years of age. This is true of both the first and second grades. It is assumed that if the number 21 years of age and above were shown, the curve would drop down from 19 as indicated at 20. The maximum at 19 may be accounted for if we assume that 'wild oats' are usually ripe at about that age. I think that most young men who are suddenly imbued with a desire to leave home for a career at sea as radio operators are about 19 years of age. (Such was my own personal experience, and while I do not advocate or approve of young men leaving school at this age, unless necessary, I believe the radio operating field offers such young men better opportunities than many other lines of work that they might follow.) There may be other interesting psychological reasons accounting for this age maximum."

I do not agree with Greaves on the "wild oats" aspect. For a few, of course, this was true, but the majority of those recruited from the amateur ranks were deeply interested in radio, wanted to see some of the world, enjoyed being of some use and making a bit of pocket money, if they did not elect to take radio up

as a career. The average amateur on a ship with good equipment available could run rings around the school-trained operator or a converted landline man of those days because of the practical experience he had reading through QRM and QRN, and other training gained in his amateur experience.

I never had any trouble getting an assignment when I was available. In fact, just before the 1912 Christmas vacation, they called me at high school to take a trip to Panama on the S. S. Aliancia, Panama R. R. Line, and asked me to bring my own second operator along as they were desperate for men. This I did with one of my high-school friends who had a first Commercial ticket. We had a most enjoyable trip to Panama in spite of some of the nastiest weather I have ever seen at sea. We went through the Canal by rail and on foot before water was in it, swam in both the Pacific and Atlantic oceans on New Year's Day, 1913, and picked up a piece of change for our trouble which was doubtless promptly spent for radio equipment. Most of my amateur friends were always able to pick up an operating assignment when they were available. In fact, at the end of each summer vacation when paid off, I was told; "Come back next summer. We will have a place for you." Pay was $35 per month for a chief operator, and $30 per month for the second wireless operator.

This period saw the formation of the Radio Club of America in 1909 and the American Radio Relay League in 1914. Amateur radio, and radio in general, owes much to the efforts of the Radio Club of America in 1910 for the fight it put up with Congress to preserve amateur radio and keep the military and commercial interests from pushing the amateurs out of existence. In 1912, it published the first amateur call list.

Many famous names were among its members, for example, E. H. Armstrong, inventor of the regenerative circuit, the superheterodyne, the super-regenerative circuit and FM. Ed Armstrong went to school with me. He built a fine receiver (for those days) using loose couplers and a Perikon detector for our physics department lecture room. My contemporaries and I spent many hours, when not busy in the classroom or laboratory, listening in on his equipment. Among others were Paul Godley, Ernest Amy, John Grinan, George Burghard, Milt Cronkhite, and Randy Runyon - they and Armstrong were all associated with the first successful trans-Atlantic transmission of amateur signals from 1BCG at Stamford, Conn., to Scotland in 1921, a cooperative project between the Radio Club of America and the American Radio Relay League. Harry Sadenwater, radio officer on the Navy NC flying boats which made the first successful flight across the Atlantic Ocean in 1919, was a club member.

Returning to the transmitting equipment of these days, the rotary spark gap was perhaps the next notable advance. This device made possible signals of improved tone by providing a musical pitch to the signal, making it more easily distinguishable through QRM and QRN. The nonsynchronous rotary was quickly adopted by the commercial stations. Then came the synchronous rotary with the beautiful 240-cycle notes of the then-American Marconi equipment. (I had them both on the Cable Ship Relay and on the Old Colony in the summer of 1913.) The 500-cycle synchronous rotary and the quenched gap were soon used by the Tropical Radio Co. on the United Fruit ships, while the German ships used the Telefunken 500-cycle quenched-gap sets, all of which put fine-toned signals, more easily read through QRN, particularly in the tropics. The U. S. Navy

quickly followed also.

The synchronous rotary and quenched gaps were used by few amateurs, since most amateur equipment was powered by 60-cycle commercial power lines. The synchronous rotary gaps were part of the motor-generators used on shipboard and mounted on the generator shaft. Hence they were not adaptable to amateur techniques.

My first transmitters using spark coils were rarely able to cover distances of more than 10 to 20 miles. Early transformer-operated equipment gave 30 to 50 miles as good DX. Working with New Jersey stations 25 to 30 miles away was usually reliable. My first New Jersey QSO was "RD," Clarence Pfeifer, later W2FG, whom I still work regularly. By 1915, on a good night, it was possible to work into Ohio with a 1-kW outfit pushing the signal out, and an Audion detector souped up by a magnet with a loose coupler pulling in the received signal.

Many boyhood friendships were formed through amateur radio prior to WW I which have continued to this day. I still work Irving Vermilya, my first two-way contact. As I type this, I hear W2EXM, Fred Parsons, warming up for our daily 2 PM schedule on 7004 kc. Fred, along with Art Boeder, W1CQR; Clarence Pfeifer, W2FG; Randy Runyon, W2AG; and Clarence McKee, K2ET; were all worked almost daily in the old days, and we still get together quite regularly on 7004 and tear off a bit of fast American Morse, much to the amazement of some of the newcomers who think it is some kind of Chinese or Japanese code. Many others, members of the Radio Club of America in its early days when I joined, I still number among my friends. Most served in the Armed Services in WW I.

I can't finish without adding some true experiences of amateurs of those days. Doubtless some hams of today go through risky experiences also. Why many of us old-timers are alive today can be explained only by the "Providence that guides drunkards and fools" to which I'll have to add "radio amateurs." No names will be cited in the incidents following. Maybe you will recognize the parties involved, maybe you won't. I'll start by telling one on myself.

There were no high trees convenient for "skyhooks" for antennas at my old home in Yonkers. I had to resort to masts. I was fortunate in having a neighbor who had charge of the Postal Telegraph Company's lines in Westchester County. His good offices were often used, along with those of his son, to help erect masts at my old home. One day, erecting a 50-foot spliced mast scrounged from the nearby woods, I was up on the mast securing a middle guy wire when the anchor for the top and middle guys to the northwest let go and the mast started to fall to the east. I was about to jump the 25 feet when my Postal friend told me to "ride it down" until a few feet from the ground and then jump where I would be clear of the mast. This I did and came off without a scratch. Several times since I have had to use this technique to save myself from broken bones and perhaps a mast falling on me. The mast base was not set deep because of rock, and the offending guy wire had used a post of a fence around the chicken yard as an anchor instead of a small stout cherry tree which could have been used better. The post was rotten just below ground and when the strain was put on it, it let go. So I learned three lessons: set poles as deep as possible, never anchor a guy wire to a fence post, and ride a mast down before jumping!

Another contemporary ham, after the New Haven Railroad was electrified (11,000 volts on the trolley line), got curious to see what would happen if a wire

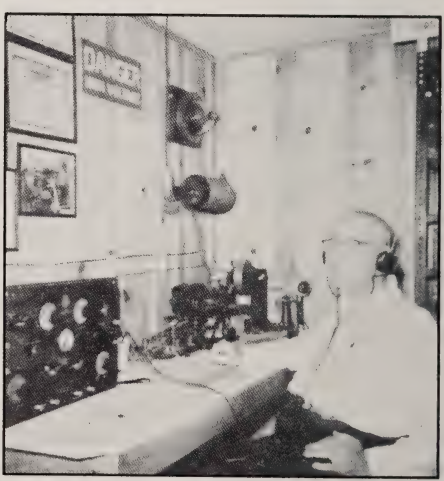
was thrown across the line. The wire did not reach the ground so nothing happened until a large freight drag came along and the wire caught on the smoke stack of the steam locomotive. There was a blinding flash! The engineer brought the train to a halt and got out to figure out what had happened and found his locomotive without a smoke stack. Of course, the wire had burned off with the stack, so he never knew "how come" his smoke stack had been "evaporated."

Two other ambitious hams were searching for daylight DX and hit the idea of flying an antenna on a large kite. All went well until the wind shifted and blew the wire across the 7500-volt three-phase feeder lines which supplied that whole end of town. Much fireworks resulted, with the lines coming down into the main line of one of the telegraph companies, cutting off electric service and putting the telegraph company out of business for some time. Fortunately, the kite was controlled by a heavy cord with the antenna wire fastened to the kite, but sagging below the cord and being paid out from a spool of wire. The flyer of the kite had the cord, instead of the wire, in his hand - so no "silent key" here.

Another used to scrounge the juice to operate his transmitter and for other experimental uses from the feeder lines for the trolley system passing by his house. A nail with a number 12 or 14 wire was driven into the feeder cable. The wire ran through trees nearby and into the basement of his house. As I recall it, the 600 volts DC was dropped to usable voltage by electrodes in a keg of salt water. Why no "silent key"? I dunno, except for that Providence previously cited.

Much more could doubtless be added to this narrative - but it is too long already - so 73 and 30.

Daniel C. McCoy



Daniel C. McCoy, W8DG, ex-2HA, was a pioneer amateur operator (1906) born in 1894. He was employed by Massie Wireless (1911), United Wireless (1911-12), and Tropical Wireless (1913-15) He attended Cornell University and became an engineer with the Frigidaire division of General Motors. A resident of Dayton, Ohio, Mr. McCoy was a charter member of AWA, a member of the Old Old Timers Club, a fellow of the Radio Club of America, and a member of the Quarter Century Wireless Association. He died in 1965.

RADIO TUBE MANUFACTURE IN AUSTRALIA

Fin Stewart
Tamworth, NSW, Australia

During the 70-year period from 1919 to 1989 there were three major radio-tube manufacturers in Australia. These were Amalgamated Wireless (Australasia) Pty. Ltd., Philips Lamps Ltd., and Standard Telephones and Cables Pty. Ltd.

AMALGAMATED WIRELESS (AUSTRALASIA) LIMITED.

This company was founded in 1919 to market radio equipment of the Radio Corporation of America and the Marconi Wireless Telegraph Co. Ltd. of England. In addition to distributing RCA and Marconi equipment, AWA manufactured its own products from the outset, mainly for marine use, but in 1920 commenced marketing radio valves of a design similar to the Cunningham Audiotron of the time. It is not clear how this came to be, because of the tie-up with the above-mentioned companies.

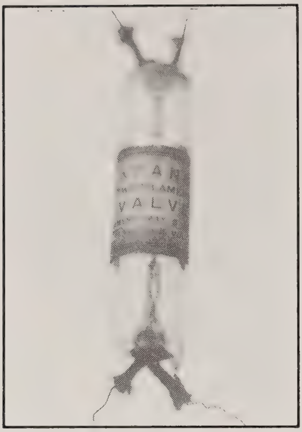
This initial tube had a paper label partly encircling it, reading "Expanse Two Filament Valve." The label went on to give electrical characteristics. The name "Expanse" was adopted by the company, later enclosed in a diamond, as their logo. It was also used for many years as their cable address. The tube, though probably an Audiotron, could well be known as the Expanse "A." The one shown, which is in the author's collection, is the only one known to exist with the label intact.

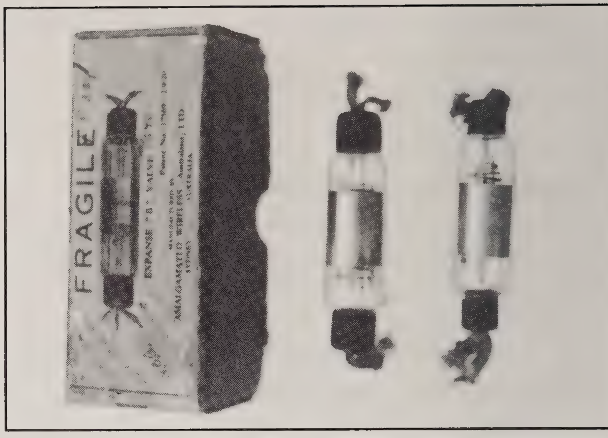
Early in 1920, the company began making their more famous Expanse "B." This one is very crude, compared to the earlier "imported" tube. The Expanse "B" has found its way into some collections outside Australia, with at least four known in the U. S. A., one in Germany, and one in Austria. The tube had a very fragile method of taking the lead-in wires through the glass and the first several thousand had ebonite cups protecting the joints. Later tubes used a smaller plastic cup. Many found today have the glass broken at the point of entry of the wires.

Just over ten thousand tubes were made. Each one had the logo and a serial number embossed on the plate. The tubes had two filaments and were used on various pieces of AWA equipment. One Australian Navy receiver is in existence with a single Expanse "B" on a panel and two Marconi V24 tubes on other panels. This particular receiver, recently acquired by a member of the Historical Radio Society of Australia, has 12 separate panels, each 3-½ inches square. The whole thing stands on an open frame.

During the next seven years, Amalgamated Wireless made six more tube types. All were triodes and were basic equivalents of some of the American and British tubes of the day. The AWA 33 was the equivalent of the Marconi/Osram DE3. It came in two styles, the one at left being made during 1924 and the one on the right in 1927. The AWA 55 was equivalent to the Marconi/Osram R5V and is the only early AWA tube not in the author's collection.

The AWA 99V was equivalent to the RCA UV-199 and resembled it closely.

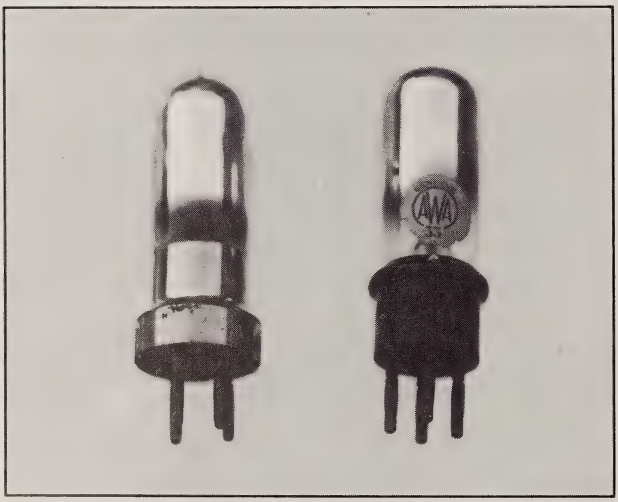




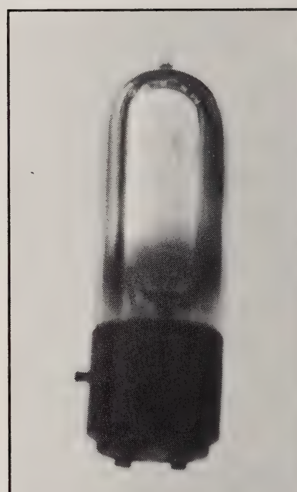
Expanse two-filament valve.

Photos: Fin Stewart

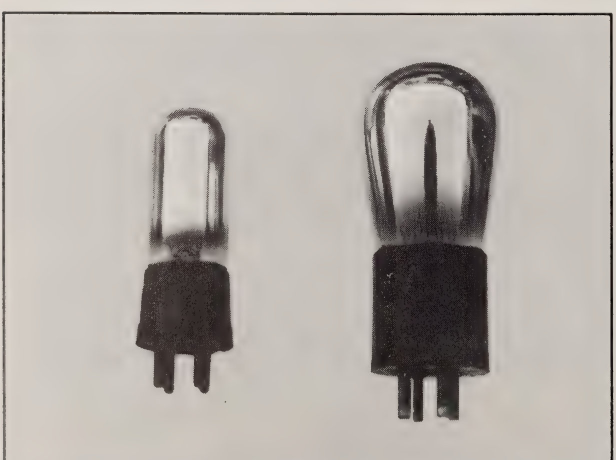
Expanse "B," two versions



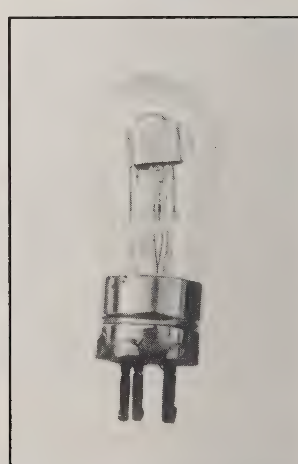
AWA 33 - two versions.



AWA 99V.



AWA 99X and 101X.



AWA 100.

It was made in four variations, the earliest having a genuine American "Shaw" UV base. The 99X was equivalent to the RCA UX-199. The tube pictured to its right is the 101X and is, of course, equivalent to the UX-201A. The base of this latter tube was the early long version of the UX base; no tubes were made with the later short base. As four versions of the 99 exist, excluding the 99X, it is not unlikely that the 101 came in as many versions, but none exist to the author's knowledge.

The next tube to be considered is the AWA 100. This tube is not listed in any printed material of the company and is not known by any old-timer or collector consulted. It should follow that it would be equivalent to the UV-200 but the element structure is much more British in appearance. This particular tube was found by the author in San Carlos, California, in 1969.

Concurrently with their own manufacture from 1924 to the late '20s, AWA marketed RCA and Marconi/Osram tubes. Production ceased in 1928 with the advent of AC radio and the mass importation of tubes from the U. S. A. and England. However, in 1933 a new factory was built in Ashfield, a suburb some six miles west of Sydney. The first tube off the assembly line was the Type 80 rectifier. Hot-branding of the base of this tube reads "Made in Australia by Amalgamated Wireless Valve Co. Ltd." The type number appeared on the glass in the familiar octagonal surround of American tubes. During the next 40 years the branding type was to change five times, finishing with a light grey paint stamped on the base. In 1934, the company was licensed to use the name "Radiotron" on all tubes.

In the mid-'30s many tubes were added to the range, mostly such American types as the 24A, 35, 57, 58, 6C6, and 2A3. One of the photos shows a 30 in a tubular bulb, which is quite rare. In this same period replacement tubes were made for British equipment. Two are pictured. These are the L410 triode and DE7 tetrode, both derivatives of Marconi/Osram.

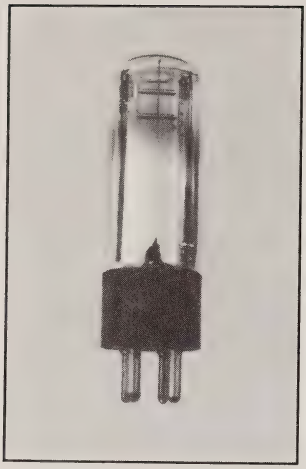
World War II saw the company tooling up to make some military tubes. Two of these are depicted together. The one at the left is the VT25, a small transmitting tube equivalent to the Marconi/Osram DAI00. The tube at the right is the AV11, a uniquely Australian radar rectifier.

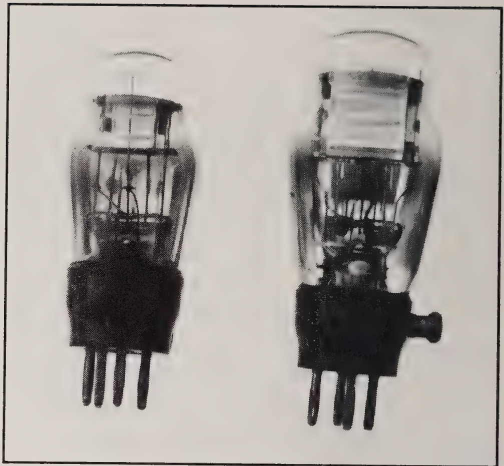
The AV designation was coined by AWA to denote special-purpose valves and, as Australians are quite "laid back," meant nothing more than "Australian Valve." Several of these were made but there was no continuance of type numbers. Research at AWA for further information produced only three additional types: AV26 ionisation pressure gauge, AV33 control diode for a saturable reactor, and AV34 thermocouple gauge.

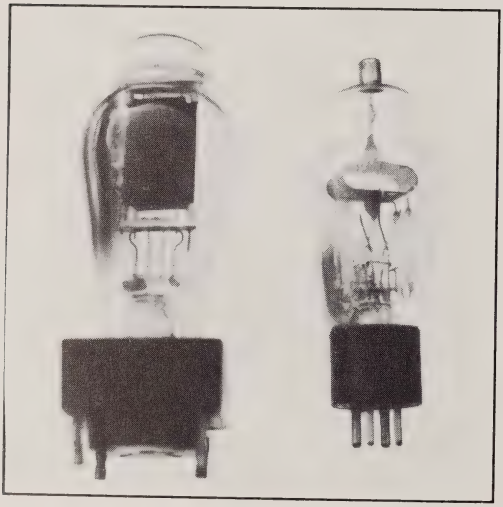
There are three other tubes not listed, but shown here. One is an AV48, which is a UHF rectifier. A second photograph shows the AV25, a demonstration triode and the AV24, a demonstration cathode-ray device. Both of these were made to be used in conjunction with equipment for physics laboratories in schools to show the actions of various currents.

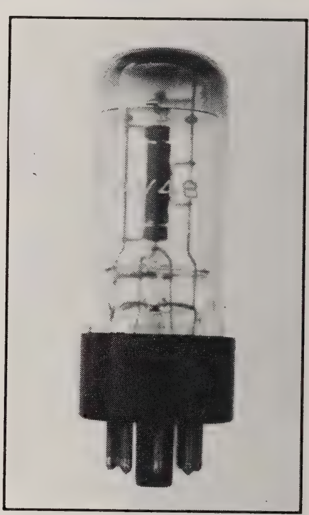
AWA also made transmitting and rectifying tubes. Two versions of the 866A are depicted. The tube with the light-bulb shape is very rare. Such tubes as the 805, 833A, and 872A were also made.

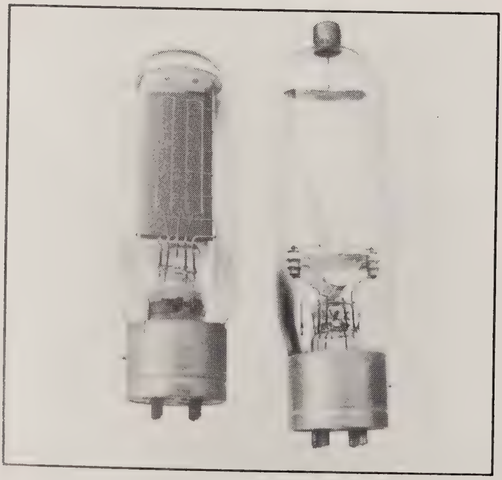
Two uniquely Australian tubes were the 6P6 and 6AR7GT. The former is actually a 42, but with the plate connection from the top to reduce internal capaci-

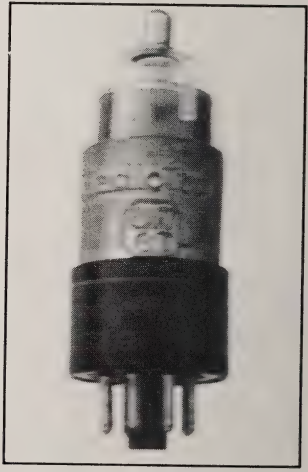

AWA 30.


AWA L410 and DE7.


AWA VT25 and AV11.


AWA AV48.


AWA AV25 and AV24.


AWA 6AR7GT.

tance. This item, which could be used as a low-power transmitter, is also rare. The tube at the right in the same photo is a 35. The 6AR7GT dual diode was unique in that it had a lead weight around the bulb as a vibration damper.

The factory closed early in 1970, a result of the natural decline in the need for radio tubes, with the space being needed for colour-television manufacture. During the 40 years from 1933 to 1973, hundreds of thousands of tubes were made at the factory; these were for the domestic radio and television market plus industrial and military use.

Not like a former tube collector, now deceased, the author was unable to be "at the right place at the right time," when the trucks took hundreds of old tubes to the dump. In fact even the AWA historian was not informed of the dumping!

PHILIPS LAMPS LIMITED

This company had been importing tubes into Australia from Holland (and to a lesser extent, England) from as early as 1922. In partnership with Osram, British Thomson-Houston, Siemens and a few others; it commenced making light bulbs at a factory at Newcastle, north of Sydney, in 1931.

Production of radio tubes started in 1936 at a large factory in Hendon, South Australia. Receiving, transmitting and industrial types were made, though the latter two lines were in limited types and quantities. The factory ceased tube manufacture in 1974 but continued until 1987 as a component maker. A letter and subsequent phone call, prior to a visit to Hendon by the author early in 1989, revealed that *all* data and tubes had been disposed of at the end of the operation.

Some tubes made at Hendon have survived. These are shown in the photographs. The first is a water-cooled transmitting triode, type TAW 12/15, capable of an output of 15 kW. Pictured nearby is a small transmitting pentode, the PEO4/15A. Philips also made a series of telephone repeater tubes in Australia: 18013, 18014, 18015 and 18016. Two of these are shown together. Another photo depicts an EL3NG, an octal-based pentode.

One unusual tube made by the factory was a compact type 47. These tubes were made specially for small domestic receivers where size was a problem.

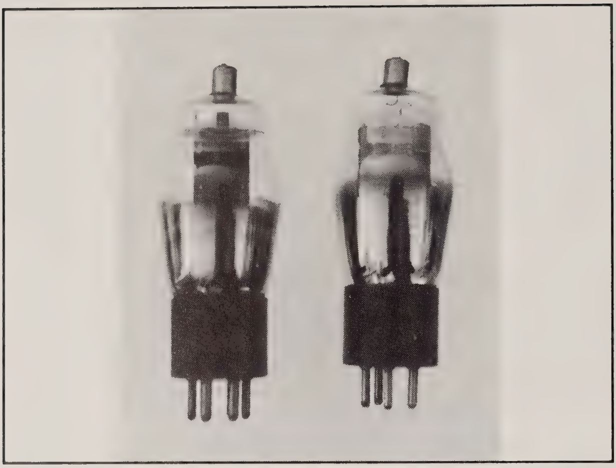
During WW II the Type 367 rectifier was made, as it was impossible to get tubes from Holland. These were replacements for the Type 366 battery charger which was widely used in Australia. Only one batch was produced. Philips manufactured transmitting tubes of the 800 series, specifically the 807, 813, and 833. Also, 866 and 872 rectifiers were produced in limited quantities.

The factory was licensed to brand tubes with the Mullard and Osram names, but these were used only on some of the receiving tubes. The Osram name appeared for only a few years before World War II.

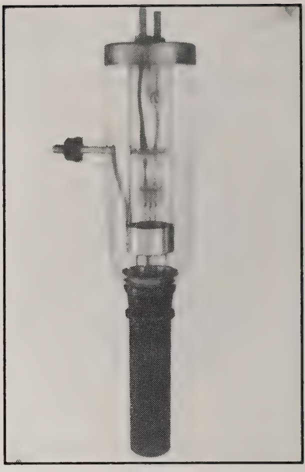
STANDARD TELEPHONES AND CABLES PTY. LIMITED

Standard Telephones and Cables Pty. Limited had been in operation in Australia for some years, marketing telephones and radio equipment, both their own and some Western Electric equipment. Tubes came from the STC factory in England, mainly telephone-repeater types such as 4101D and 4102D. The British 4019-4025 telephone-repeater series were also imported.

In 1939, the company started production of tubes at a new plant at Waterloo,

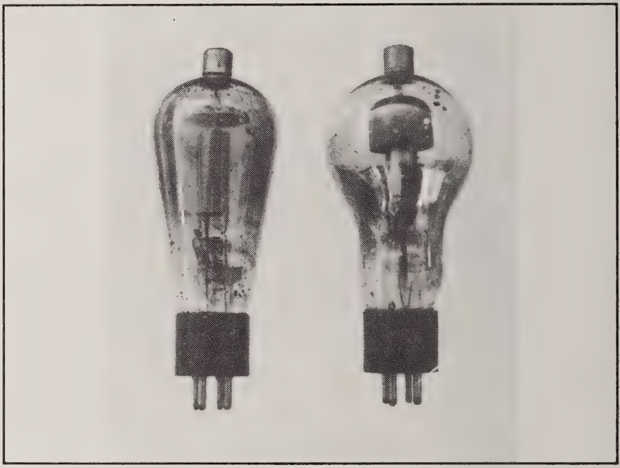


AWA 6P6 and 35.

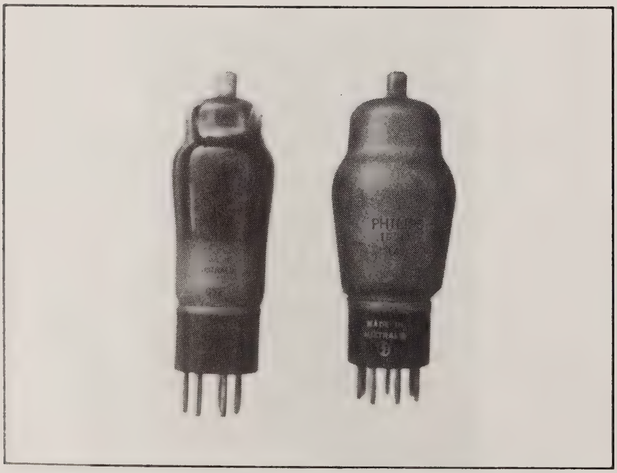


Philips TAW 12/15

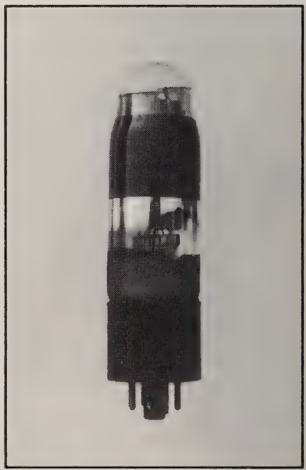
Philips PE04/15A.



AWA 866A - two versions.



Philips 18015 and 18013.



Philips EL3NG.

an inner suburb of Sydney. The first types made were the SY4101D, SY4102D, and SY4104D; and the British series. The SY (Sydney) prefix indicated that the tubes were Australian. As can be seen, both types followed their earlier American and British counterparts. The tubes were made in two variations, distinguishable by the base color. Black was the standard type, while caramel brown denoted a ruggedized version.

As STC in England made many tubes identical to the Western Electric items of the U. S. A., so did the Waterloo factory. The SY4282B had plate and grid connections from the top, like the W. E. 304B but somewhat different internally. Not much is known of other WE equivalents as, when the plant closed, all records were again destroyed.

All tubes made by STC in Australia were for industrial or transmitting purposes; they were not based on any conventional American style such as the RCA 800-series.

The SY4279Z was the largest tube made by STC in Australia. As with the Western Electric 279A in the U. S. A., these were used extensively in broadcast transmitting stations. The JF10 was a demonstration triode with a convex plate. These tubes were made only for laboratory use. Also depicted are the equivalents of British tubes, the SY4045A and SY4046A respectively. These, both pentodes, were made as replacements for use in British military equipment.

THE GARRARD AND RATCLIFF TUBE

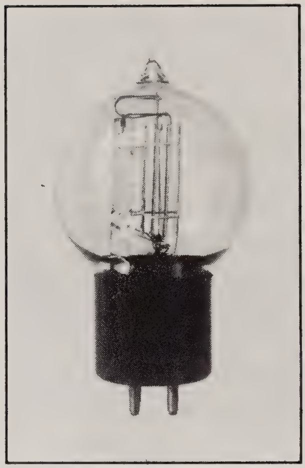
In 1923, Messrs. Garrard and Ratcliff applied for a patent on a method of sealing leading-in wires on a very crude triode they had begun making at a small workshop in King Street in the heart of Sydney. Only three of these tubes are known to exist. Apart from the leading-in "press," there is no uniformity in them at all. In fact one has the shell of a bayonet light bulb as its base, with four pins (placed in Continental or English configuration) set in a pitch-like material.

The box in the author's collection shows that the tube is a G & R 7. It is not known how many tubes were made, much less what the "7" signifies. The tubes are completely unmarked.

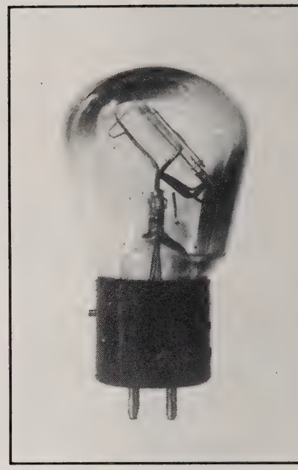
CONCLUSION

While there is no longer a tube manufacturing industry in Australia, it can be seen that there were several collectable tubes to come out of the country, and that these are well on par with some of the most sought-after types among collectors. No survey has been carried out among members of the Historical Radio Society of Australia, but it would be safe to say that most collectors of the older equipment or tubes would have at least one of the types discussed in the foregoing article. Alternatively, some of the rarer types may no longer exist.

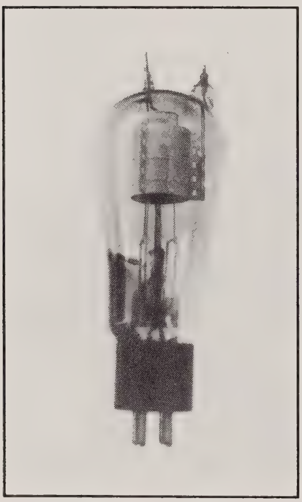
Philips compact 47.



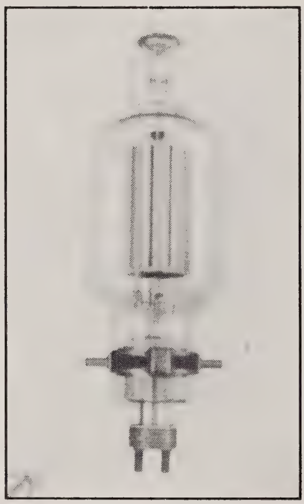
STC SY4102D.



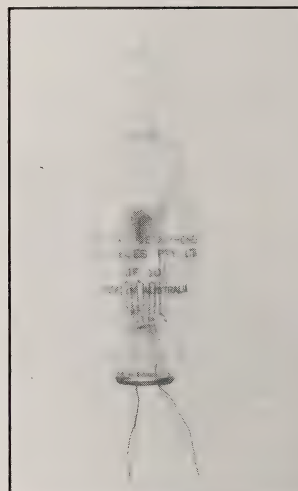
STC SY4020A.



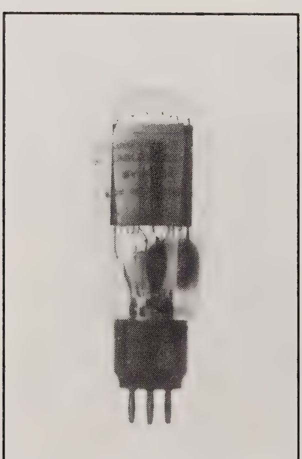
STC SY282B.



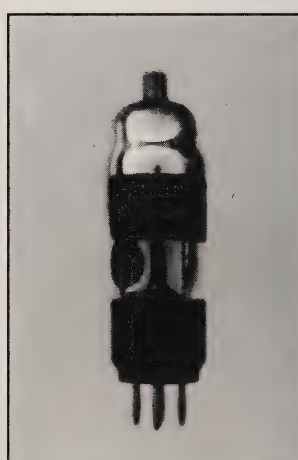
STC SY4279Z.



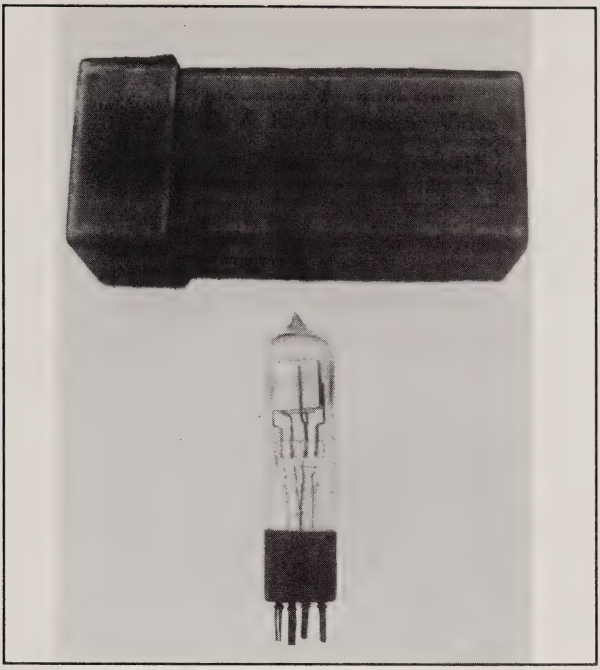
STC JF10.



STC SY4045A.



STC SY4046A.



G & R Thermionic Valve.

Fin Stewart

Born in 1940, Fin Stewart has worked in the general insurance industry since 1958. He recently moved to Tamworth in northern New South Wales due to a company reorganization.

He started collecting early light bulbs at the age of 14 and branched into collecting radios and tubes in 1959. He specialises in pre-1940 Philips light bulbs and tubes and wrote the <u>Illustrated History of Philips Radio Valves to 1935</u>. He has participated in various electricity centenaries since 1979 with portable displays, etc. He has also been closely associated with identifying tubes at the Sydney Power House Museum and his wealth of knowledge on pre-1930 tubes, in particular, frequently prompts enquiries for information on odd tubes. His collection of tubes to 1935 numbers nearly 3000, and light bulbs nearly 5000, at the time of writing.

THE MILITARY COMMUNICATIONS EXPLOSION, 1914-18

Louise Moreau, W3WRE
Glenolden, PA

After August 4, 1914, when Great Britain declared war against the Central Powers, the communications industry exerted major efforts to produce the equipment needed by the Allied war departments. Beginning slowly in the U. S. but growing rapidly after mid-1916, military preparedness would be the name of the game until the Armistice of 1918.

Some of the Allies had started with traditional forms of handling messages. Italy, for example, had devised a system of using a pair of linen strips to signal in an alphabetical code, roughly like the 92-position code of the Chappé semaphore system of Napoleonic times. The United States Signal Corps initially felt that the semaphore or wig-wag system, was still effective. The French, on the other hand, swore by the carrier pigeons that had proven successful during the Franco-Prussian War. These birds could fly beyond the line of sight which limited flag signaling. To exploit this possibility, the French had both fixed and mobile pigeon stations. General Pershing liked the French pigeon idea so much that he ordered the Signal Corps to include classes in the training and handling of the birds, even though he had also had extensive exposure to the use of wireless in his Mexican campaign. Of course, these were only a few of the systems used, for the telegraph, telephone, and radio were well established parts of military communications.

Upon entering the war, the U. S. brought many advanced techniques, for the communications industry had been expanding into different fields. The need for experienced personnel to design and develop new devices was great, as requests for new types of equipment were received. So there were experiments with instruments such as the SCR-67 portable radiotelephone developed to give voice communication into remote areas. Specialized functions like electronic intelligence were quickly improved through the research of Major Edwin Armstrong and his assistants in France.

There was an urgent request by all services for amateur radio operators. Before hostilities ended, two to three thousand amateurs had become part of military organizations. They were particularly desirable because they were prepared personnel who knew the equipment and how to use it. Also, they were familiar with message handling, and the Morse code had long been just another language to them.

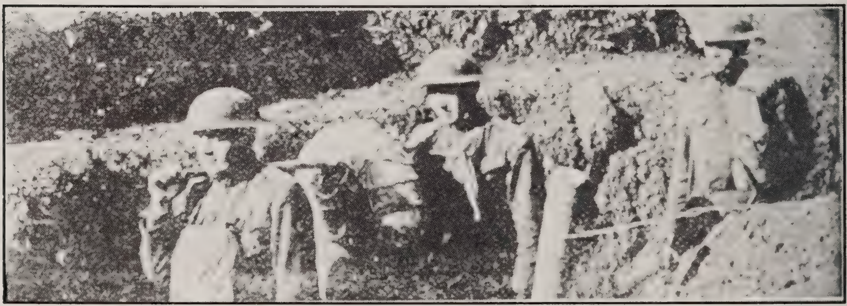
As the demands of the military grew, the services' requests for communications workers increased and women were employed to fill the vacancies to test and work with electrical apparatus. The need for radio operators brought many women into classes that were offered by professional training schools, where they learned not only the basics of code and theory, but how to work with and maintain wireless equipment. Eventually, some 30 women qualified as commercial radio operators. Some were employed in coastal stations, while a few, such as Lena Michelson, became ship operators. Lena held the distinction of

A Photographic History of the European War

Italian Army signalman with linen strips for signaling.

Freedom's Triumph

Observation post built around a tree.

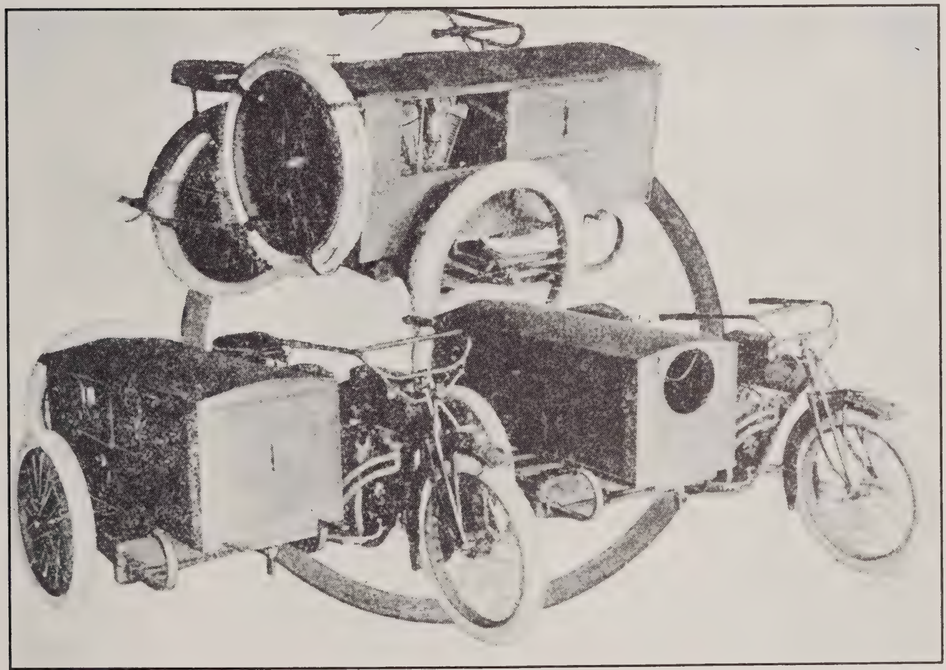


Freedom's Triumph

American signalmen laying wire in trench positions.

Electrical Experimenter, August, 1917

Civilian telephone engineers receiving Signal Corps Reserve training at AT&T headquarters in New York. SCR-49 "pack set" and its hand generator in foreground.



Electrical Experimenter, April, 1916

Radio set, transportable on two "Indian" motorcycles. 1.4-kW transmitter and tube receiver, powered by two-cylinder gasoline generator.

Circuits of Victory

Field signal battalion switchboard in the St. Mihiel salient. Captured German telephone in the background.

being the only known woman operator to send a distress signal.

The telephone was a tremendous aid at all levels of command. The need for experienced American operators with the ability to speak both French and English to work in France was answered by some 233 women, recruited mainly from the Bell System. These women were needed at command headquarters, freeing Signal Corps personnel for more hazardous duty in the field. The latter were stringing wire and installing switchboards in combat areas to connect regiments with divisions and divisions with corps headquarters, which were in turn connected with the Allied command.

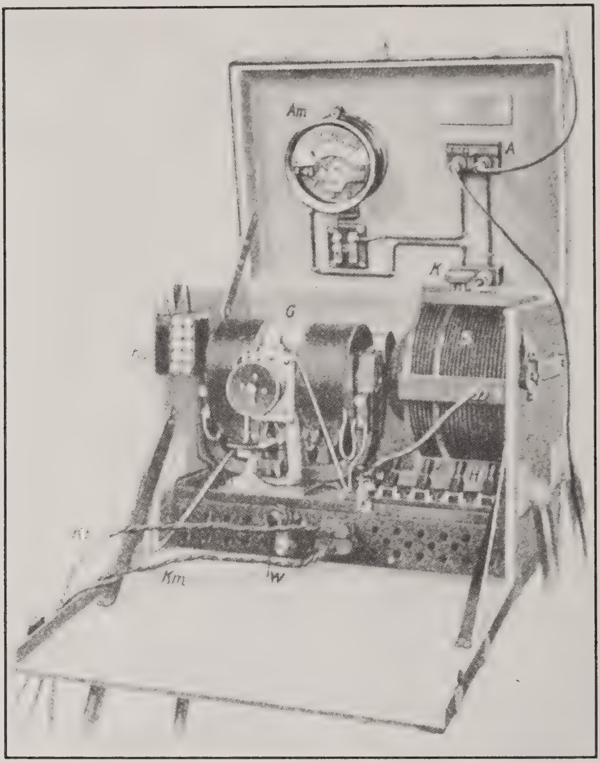
The need for landline telegraph operators in Europe was so critical that, although new operators were in training, the Signal Corps recruited "A"-wire and "bonus" operators from industry, Postal Telegraph in particular. They were among the first Signal Corps units to ship out. These landline operators were used on high-speed circuits between London and Paris. The Americans surprised the British and French by introducing these crack operators, the cream of the profession, and American wireline multiplex methods. The American telegraphers were amazed to find the French operators still using, on many of their wires, the antique register that printed dits and dashes on paper. The American system of closed-circuit telegraphy was set up, for the duration at least. This elite corps of brasspounders with their high-speed operating techniques and superior semiautomatic keys, handled the huge bulk of plain-text administrative traffic, as opposed to encrypted military messages, between the two Allied capitals. With the Phillips abbreviations, they passed an increasing volume of press traffic with minimum delays or errors.

Besides the Postal operators, there was a major contribution from Western Union and the telephone industry: there were a number of "Bell Battalions" recruited mainly from the Bell System companies, with some personnel from WU, Postal, and the independent telephone companies. About 200 men were in each of the following Telegraph Battalions:

401st (New England Telephone)
403rd (C & P Telephone Co.)
404th (New York Telephone)
405th (Mountain States)
406th (Bell of Pennsylvania)
407th (New York Telephone)
408th (Northwestern Bell)
409th (Wisconsin Telephone)
410th (Central)
411th (Pacific Telephone)
412th (Southwestern Bell)

These troops constructed 1990 miles of permanent pole line with 28,000 miles of wire, placed 40,000 miles of field wire, and installed 273 "permanent" telephone exchanges. They provided 15,000 telephones, built and ran 191 telegraph offices, and introduced use of the vacuum-tube telephone repeater and the teletypewriter. The Morse "bonus" operators were productive, but so were the American teleprinter machines.

Although the military found that the Paris-London circuits (there were at least six) answered their particular needs, they needed more than wire circuits. While North America was just a cable's length away, the traffic capacity of the existing transatlantic cables was insufficient to handle the message volume. Before the war, there had been 17 transatlantic cables in operation. The British cut the two German cables that ran via the Azores, but later spliced onto them at sea and



Electrical Experimenter, July 1916

German field transmitter of Poulsen-arc type. Arc ran in hydrogen gas from a built-in tank. Power source, a 550-V DC generator.

A Pictorial History of the European War

U. S. Navy radio class.

Electrical Experimenter, May, 1918

Edwin H. Armstrong, then a captain assigned to Paris.

Electrical Experimenter, May, 1918

Myrtle Hazard, U. S. Coast Guard radio/Morse operator from Baltimore.

Freedom's Triumph

Radio operators in the field.

G. S. Corpe

Earl Corpe, later W6LM, operating United Wireless station "PJ" at San Pedro, Calif., 1912.

G. S. Corpe

Six years later: Corpe (standing, with headphones) at an army receiving site in France. One of the thousands of amateur operators on military duty.

extended them to Britain. By 1917, six cables had failed due to an undersea earthquake and could not be repaired due to submarine activity.

The lack of cable facilities made radio critical. In response, the upgrading of radio stations for transatlantic service filled the pressing need. In the United States the Navy Department had taken control over of all radio stations at the outbreak of the war. Many were closed down for the duration of hostilities, while others, such as the Marconi-owned WII at New Brunswick, NJ, continued to operate under Navy control. Re-equipped with Alexanderson alternators, first a 50-kW unit and then a 200-kW machine, this station under the Navy callsign NFF gave dependable wireless contact among the Allies. At the end of 1918, NFF/WII was used in direct contact with Germany, handling most of the negotiations for an armistice. This traffic was passed in plain text for the information of the Central Powers and the rest of Europe, for there is no secrecy in radio.

In October 1916, the New York Herald station WHB had bent the Neutrality Act, and risked the wrath of the Navy Department, by openly broadcasting in their regular press transmissions a story about the German submarine U-53 that was lurking off the East Coast and had sunk six ships in one day. The bulletin was copied by several English passenger ships, enabling them to put into port and escape being attacked. The situation was difficult: suppressing the story could be seen as an "unneutral act" favoring Germany; transmitting it could be construed as an "unneutral act" helping the British. The Herald produced evidence from Marconi stations that the Navy press broadcast from Arlington had carried the same news before WHB.

Many ships were unable to escape from this newest form of sea warfare. However, wireless was often a lifesaver. For example, the American troopship Otranto had had wireless installed in 1910; it brought the British destroyer Mounsey to her aid in time to save over 600 men after a torpedo attack. Radio had worked the other way in 1914 for the German cruiser Emden. Her short and busy career of destroying British shipping had an ironic end: a message from the Cocos Island station, "Strange ship off entrance," sent just before the Emden destroyed the station, was received by an Australian convoy and resulted in the cruiser Sydney's terse dispatch "Have engaged the Emden and finished her."

The introduction of submarine warfare started research to find some device by which the Navy and merchant ships could detect this new danger. The Italian government sang praises of a "U-boat destroyer," attributed to Marconi, a "submarine killer" that allegedly claimed a fantastic total of some 14 in one month. In the U. S. there were several types of acoustic detection equipment. In France there was the Walser apparatus, a binaural listening device by which an observer monitored through the hull - a sort of acoustic direction finder - to detect the sounds of approaching vessels. These were of some help in locating the presence of an unseen enemy at sea.

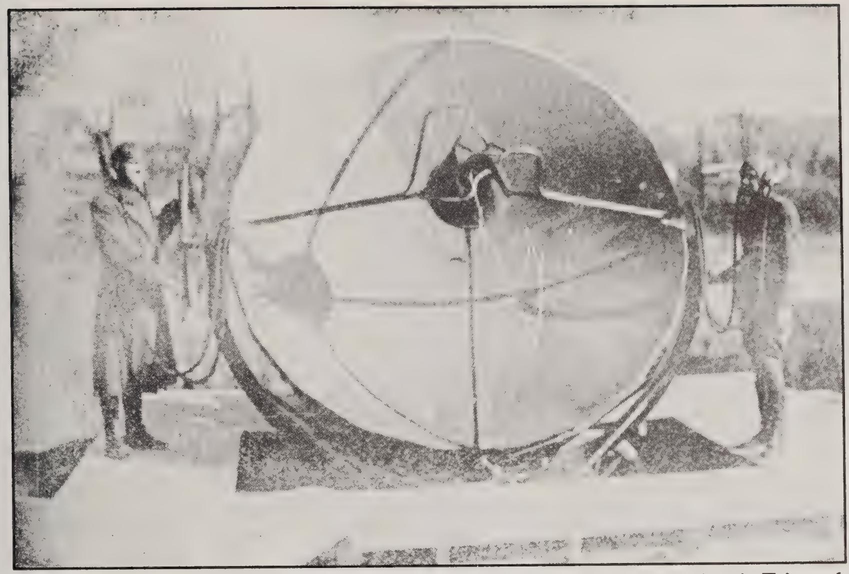
In Europe, the Allied generals were of the same mind as Napoleon when he said he wished there were some means of seeing what was going on beyond the next hill. The pigeons that General Pershing liked were not the answer. But the airplane was. Not only could it fly higher and faster than a pigeon, it also had the ability to report the observations made from the air by radio. In 1914-15 airplanes were used mainly for scouting and observation, along with tethered bal-

From Semaphore to Satellite

Signal Corps transportable station in France.

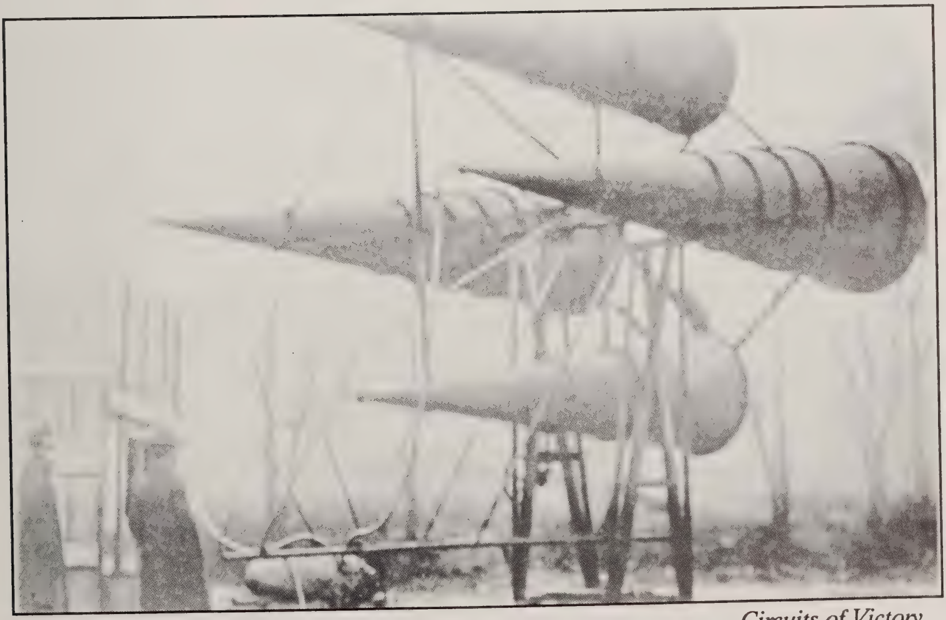
From Semaphore to Satellite

Field switchboard at a crossroads - junction of lines from regiments to division, and division to corps - in the Argonne Woods, 1918.



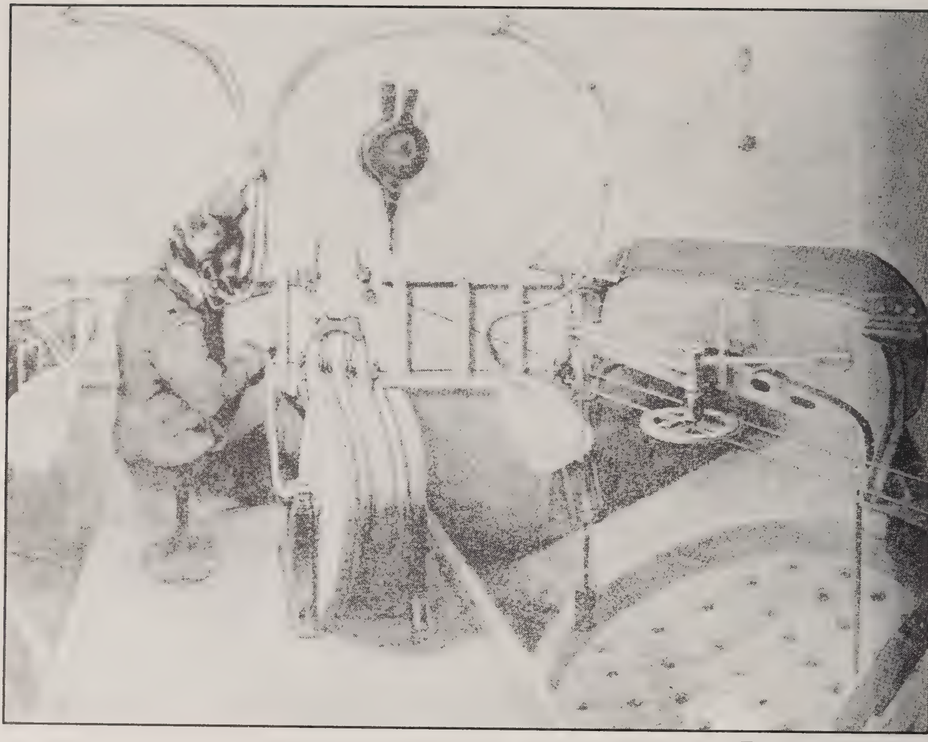
Freedom's Triumph

Acoustic aircraft-locator set, parabolic version.



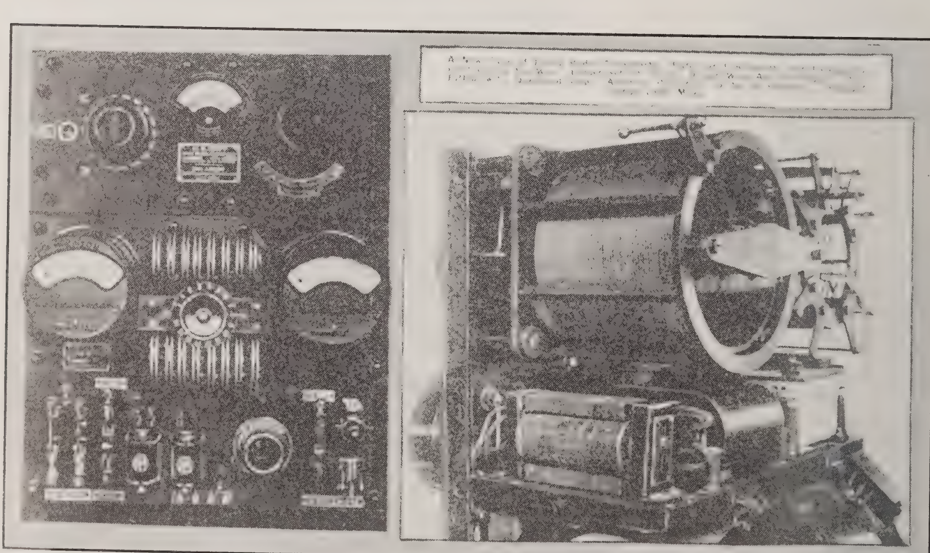
Circuits of Victory

Acoustic aircraft-locator set, phased-array version.



Freedom's Triumph

Walser through-the-hull equipment for locating submarines acoustically.



Electrical Experimenter, July, 1918

One-kW quenched-gap transmitter built by E. J. Simon, widely used by the Navy and merchant marine.

loons. Wireless was bulky and clumsy at first, not suited to aircraft installation, so the plane usually circled an assigned area and dropped written observations to a messenger stationed at a signal post. Later planes were two-seater affairs with a pilot and an aerial observer who transmitted information of the enemy's location and movements. Eventually the budding air force saw the success of the SCR-68 radiophone, both in observation use and in controlling flights of fighters.

The German Zeppelin was suitable for reconnaissance and was equipped with excellent wireless, but the British had learned to jam the wavelengths of the Central Powers. However, jamming was often undesirable: it was quite often possible to translate the transmissions and track a balloon's flight by direction finding. Often the Zeppelin operator missed parts of a message and requested that it be repeated in clear text, so all the British had to do was to wait and decipher. Thus, even the heavy raids of October 1916 were not fully successful for the Germans.

War from the air, whether the Hague Convention condoned it or not, was irresistible to use, so it became necessary to find some sort of aircraft detection device that was more effective than visual observation. Too large to be transported easily, long acoustic horns were tried to locate planes by sound, night and day. The acoustical devices were a step toward reliable detection of approaching aircraft. Somewhat less unwieldy, parabolic sound reflectors were also used to pick up the sounds of approaching aircraft.

But military communications needed more than aircraft detection and observation by scout planes. By May 1917, Signal Corps training camps had been set up in California, Kansas, and Texas. The establishment that became the major Signal Corps center in New Jersey, Little Silver, was later named Camp Alfred Vail and then Fort Monmouth. Here the training included everything from the maintenance of mobile units (four-footed and wheeled), cryptography, heliography, semaphore and wig-wag, pigeons, wire telephony and telegraphy and, of course, radio; for, on the battlefield, communications ranged across many types. For instance, listening posts were set up at advanced positions, using a buried copper mat and portable vacuum-tube amplifier to pick up impulses from enemy telegraph and telephone wires. The intelligence received from these posts was sent back via small, portable telephones and telegraph sets. The Central Powers monitored Allied wires in much the same manner. The British devised the Fullerphone telegraph set specifically to solve the problem of interception by the Germans. On at least one occasion, to avoid Allied information leaking out, the Signal Corps substituted American Indians using their own tribal language.

The Central Powers made highly effective use of radio intelligence on their Eastern Front. Owing to the lack of good wireline communications, the Russian army used wireless extensively, but with unsatisfactory cryptographic security or none. Time after time, they were surprised to find the enemy waiting for them, as in their disastrous loss of the Battle of Tannenberg.

Observation shelters located in high places were used by both sides to scout enemy troop movements and direct artillery fire. The Allied observation platforms were equipped with small, battery-powered instruments that kept in contact with ground operation to direct the fire of the batteries, scout troop movements, and signal the approach of enemy aircraft. The ground unit, in turn, signaled to the trenches and artillery units.

Circuits of Victory

Field radio station, Molliens-aux-Bois, France, June 26, 1918

Circuits of Victory

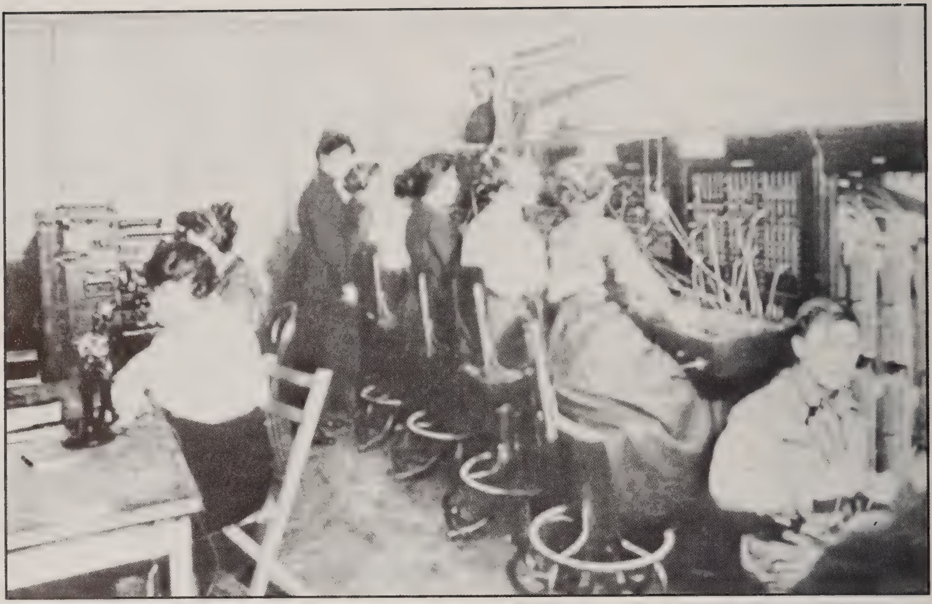
Air-to-ground radio demonstration. President Wilson talking to aircraft pilot.

Circuits of Victory

Morse section, Signal Corps telegraph office, Tours, France

Circuits of Victory

Multiplex teleprinter section, Signal Corps telegraph office, Tours



Circuits of Victory

Operating room, Toul, France. Bell operators at Second Army headquarters.

Circuits of Victory

Operating room, General Headquarters, Chaumont, France

The need for equipment to maintain contact with even the most isolated position was answered by the industry with instruments whereby companies in trenches, or single sentries, could keep the various levels of command informed through the compact trench buzzerphone (a U. S. version of the Fullerphone) that operated with either voice or code. Use of the "Service Buzzer, Model 1914" and the "power buzzer" was forbidden by the time U. S. troops entered the war, precisely because they were easy to intercept. Likewise, use of ground-return telephone circuits was forbidden.

Wireless telegraphy had been a useful asset to the Navy since the earliest installations aboard ships. It became invaluable when effective, disciplined use of radio took place after 1912. Maintaining contact while at sea had proved its value in peacetime many times. In wartime it was a vital aid; the need for large numbers of radio operators was immediately apparent. Schools for the training of radio operators were established in each naval district, where recruits learned the repair and upkeep of apparatus as well as message handling. Advanced work was taught at special schools at Harvard and Mare Island. The work of the radio operator did not merely augment that of the signalman: the radioman became the real ears and voice of the ship, for wireless telegraphy far exceeded the range of signal lamps and flags. It was vital to the monitoring of enemy as well as Allied transmissions, maintaining contact with shore stations and the Navy command, calling for help when in distress, controlling movements of escort ships and merchant vessels within convoys, or providing simultaneous communication within the entire command. The CW-936 radiophone set was used on even small vessels. The Navy established sets of radio-compass stations around all major U. S. ports, a major aid to navigation as well as to suppression of submarine attacks.

Whether from a ship's radio room, a key strapped to an aerial observer's leg, or a battlefield command post, the needs of the armed services were met by the communications industry producing the necessary equipment in just four years.

Radio figured in spreading the news of the war. Reproduced below are copies of Navy press transmissions at the time of the False Armistice (November 5, 1918) and of the real one (November 11). This traffic was taken down on shipboard by Navy radioman Andy Shafer, W8TE, later an AWA member, now deceased.

Out of wartime's critical needs, communications exploded into many fields, opening the doors of a vast industry that would affect just about every phase of our lives.

BIBLIOGRAPHY

Allen, G. H., Whitefield, H. H., and Chadwick, F. E., The Great War, Vols. 1-4 (Philadelphia: George Barrie Sons, 1919).

American Radio Relay League, Fifty Years of ARRL (Newington, CT: American Radio Relay League, 1964).

Bucher, E. E., Practical Wireless Telegraphy (New York: Wireless Press, Inc., 1917).

De Soto, C. B., Two Hundred Meters and Down (West Hartford, CT: American Radio Relay League, 1936).

U. S. Navy Press
November 5, 1918

Washington. Conditions of the armistice which the Allies and the United States imposed on Austria and which she accepted as a preliminary to the cessation of hostilities yesterday include: The total demobilization of the Austro-Hungarian Army and the immediate withdrawal of all Austro-Hungarian forces from the Western Front between the North Sea and Switzerland, evacuation of German troops from all Austro-Hungarian territory, internment of those which have not left Austro-Hungarian territory within the period of fifteen days prescribed by the Allies and the United States, delivery to the Allies and the United States of half the artillery equipment and materials at points to be designated, including coal, immediate reparation without reciprocity on the part of the Allies and the United States of all prisoners of war and interned subjects of the latter and the cession to the Allies and the United States of certain territories to be occupied by them and administered under their supervision.

The Allies and the United States are to have full movement by rail and water through Austro-Hungarian territory and to occupy such strategic points as they deem necessary. The naval conditions of the armistice require (among other things) surrender to the Allies and the United States of fifteen Austro-Hungarian submarines and all German submarines in Austro-Hungarian waters now or which may hereafter appear within such waters, disarmament of all other submarines and their transfer to the supervision of the Allies and the United States: surrender of three battleships, three light cruisers, nine destroyers, twelve torpedo boats, one mine layer, and six Danube monitors to be designated by the Allies and the United States. (stop) Occupation by the Allies and the United States of the land and naval fortifications and the islands which form the defenses of the dockyards and arsenal at Pola, and of the defensive works along the Danube. All the surface vessels including river craft, are to be paid off and completely disarmed under supervision of the Allies and the United States and freedom of navigation is to be given to all naval and merchant ships of the Allies and the United States. Three hundred thousand prisoners and five thousand guns had been enumerated by the Allies on the Italian front before the armistice went into effect. There were captured also immense stores of materials.

U. S. Navy Press
November 11, 1918

Washington. Armistice signed by Germany effective six o'clock morning Washington time and hostilities ceased. President Wilson at one o'clock read terms of armistice at joint session Senate and House. At same hour Premier Clemenceau read terms to French Chamber Deputies. Following proclamation given out by President this morning.

"My fellow countrymen: the armistice was signed this morning. Everything for which America has fought has been accomplished. It will now be our fortunate duty to assist by example, by sober friendly counsel and by material aid, in the establishment of just democracy throughout the world."

Terms of armistice include: Immediate evacuation all occupied territory completed within fourteen days, including Alsace-Lorraine and Luxembourg - the surrender huge amounts guns and equipment, evacuation left bank Rhine which Allies will occupy - will hold all principal crossings - surrender vast amount rolling stock in occupied territories - Bucharest and Brest treaties annulled - unconditional surrender all German forces East Africa - reparation for all damage done - withdrawal all German troops from Russian, Turkish and Roumanian territory. Naval terms include: Immediate cessation hostilities at sea and definite information given as to location and movements all German ships - notification given neutrals that freedom of navigation in all territorial waters is given to naval and merchant submarines *[sic]* of Allied and associated powers - questions of neutrality being waived - all naval prisoners to be returned by Germany without reciprocity - surrender of hundred and sixty submarines in ports specified - all other submarines to be paid off and completely disarmed. Following surface warships to be disarmed and interned neutral or Allied ports - with only caretakers on board: six battle cruisers, ten battleships, eight light cruisers and fifty modern destroyers, all others to be concentrated at ports designated by Allies, paid off, completely disarmed, and placed under Allied supervision. Allies to have right to sweep up all mine fields and obstructions laid by Germans outside German territorial waters, their positions to be indicated. Free access Baltic for Allied ships. To enforce this Allies to occupy all fortifications, all entrances from Cattegat [sic] to Baltic and to sweep all mines even in territorial waters. Existing Allied blockade to remain unchanged and German merchant ships found at sea liable to capture. All naval aircraft to be concentrated and immobilized at specified German bases. In evacuating Belgian ports and coasts Germany shall abandon all merchant ships, tugs, lighters, material for inland navigation, aircraft, arms and stores, etc. All Black Sea ports to be evacuated by Germans and Russian ships to be handed over to Allies to returned without reciprocity. No destruction ships or material to be permitted. German government to notify all neutrals restrictions placed on trading with Allies immediately canceled. No transfer German shipping to any neutral flag after signing armistice.

Hancock, H. E., Wireless at Sea: The First Fifty Years (Chelmsford, England: Marconi International Communications Co., 1950).

Harlow, A. F., Old Wires and New Waves (New York: Appleton-Century, 1936).

Michaelis, A. R., From Semaphore to Satellite (Geneva: International Telecommunications Union, 1965).

Scrivner, G. P., Regulations for United States Military Telegraph Lines, Alaskan Cable, and Telegraph Stations, United States Signal Corps (Washington: U. S. Government Printing Office, 1915, corrected 1917).

Terrett, D., The Signal Corps: The Emergency (Washington: U. S. Department of the Army, 1956).

--, War Manual of the Great Conflict of 1914 (New York: Doubleday, Page, and Co., 1914).

Whitehouse, A., The Zeppelin Fighters (New York: Doubleday, Page, and Co., 1926).

Woman's Weekly, Freedom's Triumph - The Why, When, and Where of the European Conflict (Chicago: Magazine Circulation Co., Inc., 1919).

Fiftieth Anniversary Golden Year Book, 1909-1959 (New York: Radio Club of America, 1959).

Lavine, A. L., Circuits of Victory (New York: Doubleday, Page, and Co., 1921).

Louise R. Moreau

Educated in Johnstown, PA and at the University of Pittsburgh, Lou was licensed as W3WRE in 1953. She has written extensively on the history of the telegraph key, based on her knowledge of CW communication.

Lou is a Fellow and a Life Member of the Radio Club of America and is affiliated with numerous other radio organizations. She has been the recipient of many awards, including the Ralph Batcher Award of the Radio Club of America, the President's Award for History of Women in Communications, Young Ladies Radio League, and the AWA Houck Award for Documentation. In 1976 she was nominated to the Telegraph Hall of Fame.

THE U. S. PATENTS OF ALEXANDERSON, CARSON, COLPITTS, DAVIS, GERNSBACK, HOGAN, LOOMIS, PUPIN, RIDER, STONE, AND STUBBLEFIELD

David W. Kraeuter
Washington, Pennsylvania

The following provides primary information about the 737 U. S. patents of Ernst Alexanderson (344), John R. Carson (23), Edwin Colpitts (23), Harry P. Davis (75), Hugo Gernsback (37), John V. L. Hogan (31), Mahlon Loomis (6), Michael Pupin (34), John F. Rider (8), John Stone Stone (152), and Nathan B. Stubblefield (4). Patent information for ten other radio inventors - Armstrong, Conrad, de Forest, Du Mont, Farnsworth, Fessenden, Fleming, Kent, Marconi, and Zworykin - appears in Volume 5 of the AWA Review, pages 143-190.

Readers may not recognize some of these names. Alexanderson, who worked in the early years of the century with Reginald Fessenden, lived long enough to receive a patent for a color television system in 1955. Carson devised the single-side-band carrier-suppressed method of transmission in wide use today. Colpitts (somewhat reluctantly) accepted credit for the oscillator circuit which bears his name. Davis was a founder of KDKA. Gernsback was known widely as a publisher in several fields and is credited with coining the term "science fiction." Hogan invented one-dial tuning and founded television station W2XR in New York in 1929; today it is WQXR-AM-FM. Loomis, a dentist by profession, demonstrated wireless transmission of a sort before members of Congress in 1868. Pupin invented (or discovered) the electrical resonator; Edwin Armstrong was one of his students. Rider, of course, was the publisher of the Perpetual Trouble Shooter's Manual and numerous other items on electronic theory and practice. In what had to be a banner day for him and the patent office, Stone was granted 36 patents on August 16, 1904, 31 of which were for "space telegraphy." Stubblefield was one of many claimants to the elusive title "Inventor of Radio"; he transmitted wireless voice and music in 1892. More information about most of these inventors may be found in various volumes of the Dictionary of American Biography.

Most of the patent information here is presented as found in the indexes to the U. S. patents, and generally has not been verified in the U. S. Patent Gazette. I do not claim to list all the patents of each of these inventors. Often devices patented in the U. S. patent system were also patented in the English and German systems as well. This practice may explain seeing much higher counts of patents in the literature. One of Gernsback's biographers states that Gernsback patented about 80 electronic devices, but the 37 listed here were all I was able to locate in the indexes under his name. (Does anyone have any information about Gernsback's Osophone, a device for transmitting through bone, that he supposedly patented in 1928?)

Anyone having corrections to make to the text is invited to write to me, c/o Washington and Jefferson College, Washington, PA 15301. I thank Bev Martin for her help in proofreading, and the staff of the Science and Technology Divi-

sion of the Carnegie Library of Pittsburgh, where most of this information was gathered.

Patent citations take this form: *Title. Number. Date*. When the Gazette reference is known, it follows, given as *volume: page*.

ERNST ALEXANDERSON (1878-1975)

Patents in Chronological (Patent Number) Order

Synchronous motor. 785,532. March 21, 1905. 115:724.
Two-speed winding for three-phase motors. 785,533. March 21, 1905. 115:725.
Winding for three-phase motors. 785,995. March 28, 1905. 115:942.
Alternating-current generator. 789,404. May 9, 1905. 116:444.
Alternating-current generator. 789,476. May 9, 1905. 116:484.
Voltage-regulator. 805,253. November 21, 1905. 119:849.
Protective means for alternating-current systems. 819,627. May 1, 1906. 122:260.
Ground-detector and cut-out. 825,286. July 10, 1906. 123:327.
Means for controlling self-exciting generators. 829,133. Aug. 21, 1906. 123:2462.
Voltage-regulator. 829,826. August 28, 1906. 123:2869.
Alternating-current generator. 839,358. December 25, 1906. 125:2503.
Motor-winding. 841,609. January 15, 1907. 126:1014.
Alternating-current motor. 841,610. January 15, 1907. 126:1016.
Dynamo-electric machine. 849,713. April 9, 1907. 127:2170.
Alternating-current motor. 859,358. July 9, 1907. 129:579.
Frequency-changer. 859,359. July 9, 1907. 129:580.
Alternating-current motor. 861,012. July 23, 1907. 129:1472.
Dynamo-electric machine. 861,072. July 23, 1907. 129:1496.
Induction-motor. 872,550. December 3, 1907. 131:1244.
Alternating-current motor. 873,702. December 17, 1907. 131:1693.
Starting motor-converter. 876,923. January 21, 1908. 132:481.
Compensated motor. 876,924. January 21, 1908. 132:481.
Self-excited alternator. 881,647. March 10, 1908. 133:415.
Induction-motor control. 882,606. March 24, 1908. 133:787.
Motor control. 885,128. April 21, 1908. 133:1727.
Self-exciting generator. 895,933. Aug. 11, 1908. 135:1297. [With E. H. Widegren.]
Synchronous motor. 897,507. September 1, 1908. 136:87.
Alternating-current motor. 897,508. September 1, 1908. 136:87.
Induction-motor control. 901,513. October 20, 1908. 136:1608.
Telephone-relay. 902,195. October 27, 1908. 136:1858.
Alternating-current high-frequency generator. 905,621. Dec. 1, 1908. 137:1147.
Electric motor. 919,514. April 27, 1909. 141:946.
Single-phase motor. 920,710. May 4, 1909. 142:203.
Induction-generator. 920,809. May 4, 1909. 142:235.
Alternating-current motor. 920,896. May 4, 1909. 142:262.
System of electric distribution. 921,786. May 18, 1909. 142:620.
Electric motor. 923,311. June 1, 1909. 143:66.
Single-phase-motor control. 923,312. June 1, 1909. 143:67.
Alternating-current motor. 923,753. June 1, 1909. 143:219.
Alternating-current motor. 923,754. June 1, 1909. 143:219.

Single-phase-motor control. 927,397. July 6, 1909. 144:230.
Alternating-current motor. 927,398. July 6, 1909. 144:231.
Alternating-current-motor control. 927,399. July 6, 1909. 144:231.
Single-phase motor. 935,881. October 5, 1909. 147:87.
Motor control. 936,071. October 5, 1909. 147:150.
Motor-control system. 940,112. November 16, 1909. 148:630.
Alternating-current-motor control. 946,751. January 18, 1910. 150:648.
Dynamo-electric machine. 949,345. February 15, 1910. 151:577.
Single-phase-motor control. 949,346. February 15, 1910. 151:577.
Electric locomotive. 949,347. February 15, 1910. 151:578.
Commutator-motor. 949,992. February 22, 1910. 151:831.
Single-phase commutator-motor. 951,357. March 8, 1910. 152:319.
Single-phase commutator-motor. 953,366. March 29, 1910. 152:1080.
Overload protective device. 954,845. April 12, 1910. 153:429.
Motor control. 957,454. May 10, 1910. 154:356.
Braking alternating-current motors. 967,295. August 16, 1910. 157:541.
Electric braking. 967,296. August 16, 1910. 157:542.
Electric braking. 974,224. November 1, 1910. 160:45.
Motor control. 996,390. June 27, 1911. 167:889.
Reinforcer for telephone-circuits. 996,391. June 27, 1911. 167:890.
Telephone relay and system. 996,445. June 27, 1911. 167:908.
Manufacturing rotating bodies for high-speed machinery. 998,734. July 25, 1911. 168:846.
High-frequency alternator. 1,008,577. November 14, 1911. 172:367.
Alternating-current motor. 1,019,402. March 5, 1912. 176:136.
Single-phase motor. 1,021,289. March 26, 1912. 176:885.
Method of and apparatus for relaying high-frequency currents. 1,042,069. October 22, 1912. 183:910.
Alternating-current motor. 1,060,731. May 6, 1913. 190:58.
Alternating-current motor. 1,068,404. July 29, 1913. 192:997.
Means for compensating polyphase alternating-current commutation-motors. 1,080,403. December 2, 1913. 197:172.
Air-inlet valve for carbureters. 1,083,789. January 6, 1914. 198:174.
Electric braking with alternating-current motors. 1,089,384. March 3, 1914. 200:240.
Dynamo-electric machine. 1,091,613. March 31, 1914. 200:1170.
Dynamo-electric machine. 1,091,614. March 31, 1914. 200:1171.
Dynamo-electric machine. 1,092,420. April 7, 1914. 201:102.
Phase-balancer. 1,093,594. April 21, 1914. 201:575.
Alternating-current-motor control. 1,098,656. June 2, 1914. 203:102.
Method of and apparatus for indicating the speed of electric motors. 1,100,280. June 16, 1914. 203:737.
Telephone system. 1,102,628. July 7, 1914. 204:143.
High-frequency alternator. 1,110,028. September 8, 1914. 206:455.
High-frequency alternator. 1,110,029. September 8, 1914. 206:456.
Bearing. 1,110,030. September 8, 1914. 206:456.
Induction-motor. 1,119,741. December 1, 1914. 209:288.
Neutralizing inductive disturbances. 1,120,992. December 15, 1914. 209:811.

High-frequency alternator. 1,126,334. January 26, 1915. 210:1222.
System of electrical distribution. 1,150,652. August 17, 1915. 217:936.
Split-phase system. 1,170,211. February 1, 1916. 223:161.
Selective tuning system. 1,173,079. February 22, 1916. 223:1312.
Boiler and heating arrangement therefor. 1,174,375. March 7, 1916. 224:123.
Frequency transformation. 1,174,793. March 7, 1916. 224:280.
Phase-balancer. Reissue. 14,133. May 16, 1916. 226:1046.
Induction-motor. 1,185,461. May 30, 1916. 226:1709.
Alternating-current motor. 1,194,265. August 8, 1916. 229:546.
Alternating-current-commutator motor. 1,194,923. August 15, 1916. 229:821.
Controlling alternating currents. 1,206,643. November 28, 1916. 232:1175.
High-speed rotating body. 1,208,441. December 12, 1916. 233:624.
System of ship propulsion. 1,215,094. February 6, 1917. 235:214.
System of ship propulsion. 1,215,095. February 6, 1917. 235:215.
Power-transmitting mechanism. 1,223,924. April 24, 1917. 237:1125.
High-frequency alternator. 1,229,856. June 12, 1917. 239:548.
Automatic control of phase-converters. 1,233,952. July 17, 1917. 240:862.
Regulator for phase-balancers. 1,233,953. July 17, 1917. 240:863.
System of electrical distribution. 1,242,632. October 9, 1917. 243:410.
Apparatus for producing an electromotive force of special wave form. 1,250,752. December 18, 1917. 245:748.
Internal-combustion hydraulic pump. 1,259,338. March 12, 1918. 248:440.
Rotor for dynamo-electric machines. 1,261,673. April 2, 1918. 249:193.
Multispeed alternating-current motor. 1,263,992. April 23, 1918. 249:920.
Condenser. 1,266,377. May 14, 1918. 250:444.
Electrical system of power transmission. 1,268,662. June 4, 1918. 251:168.
Automatic control of phase-converters. Reissue. 14,510. Aug. 27, 1918. 253:921.
Motor-control system. 1,280,624. October 8, 1918. 255:167.
Motor excitation. 1,289,592. December 31, 1918. 257:956.
System of electric ship propulsion. 1,289,593. December 31, 1918. 257:956.
Series-multiple control. 1,300,542. April 15, 1919. 261:485.
System of phase modification. 1,300,543. April 15, 1919. 261:485.
System of phase modification. 1,300,544. April 15, 1919. 261:485.
Starting phase-converters. 1,300,545. April 15, 1919. 261:486.
Speed control of induction-motors. 1,301,632. April 22, 1919. 261:742. [With D. C. Prince.]
Electrical system of power transmission. 1,304,239. May 20, 1919. 262:393.
Electric system of ship propulsion. 1,304,240. May 20, 1919. 262:393. [With S. P. Nixdorff.]
Wireless-telephone system. 1,313,041. August 12, 1919. 265:258.
Wireless signaling system. 1,313,042. August 12, 1919. 265:258.
Bearing. 1,315,069. September 2, 1919. 266:109.
System of frequency transformation. 1,316,995. September 23, 1919. 266:537.
Radiosignaling system. 1,320,959. November 4, 1919. 268:113.
Means for controlling alternating currents. 1,328,473. Jan. 20, 1920. 270:397.
Method of and means for controlling high-frequency alternating currents. 1,328,610. January 20, 1920. 270:423.
Means for controlling alternating currents. 1,328,797. Jan. 20, 1920. 270:457.

Means for controlling alternating currents. 1,334,126. March 16, 1920. 272:481.
Regulating system for alternating-current circuits. 1,337,875. April 20, 1920. 273:546.
Method of and means for controlling electrical energy. 1,340,101. May 11, 1920. 274:348.
Wireless signaling system. 1,350,911. August 24, 1920. 277:711.
Radioreceiving system. 1,350,912. August 24, 1920. 277:711.
Antenna. 1,360,167. November 23, 1920. 280:732.
Antenna. 1,360,168. November 23, 1920. 280:732.
Radiosignaling system. 1,360,169. November 23, 1920. 280:732.
Series-multiple control. 1,365,441. January 11, 1921. 282:313.
High-frequency alternator. 1,366,627. January 25, 1921. 282:629.
High-frequency alternator. 1,369,601. February 22, 1921. 283:674.
Radio-receiving system. 1,373,931. April 5, 1921. 285:108.
System of electrical distribution. 1,375,991. April 26, 1921. 285:638.
Radio-receiving system. 1,375,992. April 26, 1921. 285:638.
Means for frequency transformations. 1,382,877. June 28, 1921. 287:650.
Cooling dynamo-electric machines. 1,382,878. June 28, 1921. 287:650.
Apparatus for producing and distributing electric-current waves of radio frequency. 1,386,830. August 9, 1921. 289:244.
System of radio communication. 1,400,847. December 20, 1921.
Removing sleet from antennae. 1,404,726. January 31, 1922.
Amplifying system. 1,419,797. June 13, 1922.
Rotary transforming apparatus. 1,420,398. June 20, 1922.
High-frequency alternator. 1,426,943. August 22, 1922.
Radiosignaling system. 1,426,944. August 22, 1922.
Control system. 1,461,571. July 10, 1923.
Unidirectional radio receiving system. 1,465,108. August 14, 1923.
Wireless signaling system. 1,465,961. August 28, 1923.
Wireless signaling system. 1,465,962. August 28, 1923.
High-frequency signaling system. 1,466,263. August 28, 1923.
Radio receiving system. 1,477,413. December 11, 1923.
Electric ship propulsion. 1,481,853. January 29, 1924.
Electric ship propulsion. 1,481,882. January 29, 1924.
System of motor control. 1,490,720. April 15, 1924.
Radio receiving system. 1,491,372. April 22, 1924.
Double-squirrel-cage synchronous motor. 1,495,969. May 27, 1924.
High-frequency signaling system. 1,500,785. July 8, 1924.
Wireless signaling system. 1,501,830. July 15, 1924.
Wireless signaling system. 1,501,831. July 15, 1924.
Wireless signaling system. 1,508,151. September 9, 1924.
Radio transmitting system. 1,517,816. December 2, 1924.
Controlling alternating currents. 1,522,221. January 6, 1925.
Electron-discharge device. 1,535,082. April 21, 1925.
System of distribution. 1,537,055. May 12, 1925.
Radio receiving system. 1,546,878. July 21, 1925.
Signaling system. 1,549,737. August 18, 1925.
Surge preventer. 1,554,698. September 22, 1925.

Operating electric motors. 1,563,004. November 24, 1925.
Radio signaling system. 1,564,807. December 8, 1925.
Electric ship propulsion. 1,579,051. March 30, 1925.
Transmitting angular motion. 1,600,204. September 14, 1926.
Alternating-current-motor control. 1,603,102. October 12, 1926.
High-frequency signaling system. 1,610,073. December 7, 1926.
System of distribution. 1,620,506. March 8, 1927.
Controlling alternating currents. 1,634,970. July 5, 1927.
High-frequency signaling system. 1,648,711. November 8, 1927.
Voltage regulator. 1,652,923. December 13, 1927.
Regulating system. 1,655,035. January 3, 1928.
Control of electric power. 1,655,036. January 3, 1928.
Locomotive control. 1,655,037. January 3, 1928.
Power-factor control system. 1,655,038. January 3, 1928.
Speed-control system. 1,655,039. January 3, 1928.
Control of electric power. 1,655,040. January 3, 1928.
Regulating apparatus. 1,655,041. January 3, 1928.
Speed-control system. 1,655,042. January 3, 1928.
Electric motor. 1,667,647. April 24, 1928.
Control system. 1,669,153. May 8, 1928.
System of electric ship propulsion. 1,676,312. July 10, 1928.
Antenna. 1,677,698. July 17, 1928.
System of electrical distribution. 1,677,699. July 17, 1928.
System of electrical distribution. 1,677,700. July 17, 1928.
System of distribution. 1,680,758. August 14, 1928.
Circuit-control apparatus. 1,691,423. November 13, 1928.
Electric apparatus. 1,694,244. December 4, 1928.
Electrical transmission of pictures. 1,694,301. December 4, 1928.
Transmission of pictures. 1,694,302. December 4, 1928.
Oscillation generator. 1,698,290. January 8, 1929.
Electric ship propulsion. 1,701,350. February 5, 1929.
Power-amplifying means. 1,706,094. March 19, 1929.
Rectifying apparatus. 1,718,515. June 25, 1929.
Control of electric power. 1,719,866. July 9, 1929.
Signaling system. 1,722,998. August 6, 1929.
System of ship propulsion. 1,723,906. August 6, 1929.
Radio receiving system. 1,723,907. August 6, 1929.
Ignition system. 1,723,908. August 6, 1929.
Speed-control system. 1,736,689. November 19, 1929.
Speed-indicating system. 1,747,041. February 11, 1930.
Transmission of pictures. 1,752,876. April 1, 1930.
Radiotelegraphy. 1,768,433. June 24, 1930.
Method of and apparatus for multiplex signaling. 1,771,700. July 29, 1930.
Stabilization of tuned radio frequency amplifiers. 1,775,544. September 9, 1930.
Radio signaling system. 1,775,801. September 16, 1930.
Transmission of pictures. 1,783,031. November 25, 1930.
Control system. 1,787,299. December 30, 1930.
Electric discharge device. 1,787,300. December 30, 1930.

Method and apparatus for picture transmission by wire or radio. 1,787,851. January 6, 1931. [With R. H. Ranger.]
Radio signaling system. 1,790,646. February 3, 1931.
Transmission of pictures. 1,792,264. February 10, 1931.
Radio signaling system. 1,797,039. March 17, 1931.
System of distribution. 1,800,002. April 7, 1931.
Radio signaling system. 1,814,813. July 14, 1931.
Transmission of pictures. 1,830,586. November 3, 1931.
System of distribution. 1,835,131. December 8, 1931.
Signaling. 1,839,455. January 5, 1932.
Eliminating fading. 1,853,021. April 12, 1932.
Picture transmission. 1,857,130. May 10, 1932.
System for producing high frequency oscillations. 1,866,337. July 5, 1932.
Picture transmission apparatus. 1,866,338. July 5, 1932.
Alternating current commutator machine. 1,867,396. July 12, 1932.
Signaling by phase displacement. 1,882,698. October 18, 1932.
Television receiver. 1,889,587. November 29, 1932.
Electrical system. 1,896,534. February 7, 1933.
Amplifying electrical impulses. 1,906,441. May 2, 1933. [With R. D. Kell.]
Indicating system for aircraft. 1,907,471. May 9, 1933.
Indicating altitude from aircraft. 1,913,148. June 6, 1933.
System of electric power transmission. 1,917,081. July 4, 1933.
System of electric power transmission. 1,917,082. July 4, 1933. [With P. L. Alger and S. P. Nixdorff.]
Radiant energy guiding system for airplanes. 1,917,114. July 4, 1933. [With John H. Hammond.]
Regenerative electric regulator. 1,917,146. July 4, 1933. [With S. P. Nixdorff.]
Electrical transmission system. 1,921,718. August 8, 1933.
Television apparatus. 1,935,427. November 14, 1933.
Electric valve converting system. 1,937,377. November 28, 1933.
Sound-motion picture producer. 1,937,378. November 28, 1933.
Electric valve converting system. 1,939,428. December 12, 1933.
Electric valve converting system. 1,939,429. December 12, 1933.
Electric valve excitation circuits. 1,954,661. April 10, 1934. [With A. H. Mittag and E. L. Phillipi.]
Automatic steering system. 1,958,258. May 8, 1934.
Method and means for determining altitude from aircraft. 1,969,537. Aug. 7, 1934.
Electric translating system. 1,969,538. August 7, 1934.
Radioreceiver. 1,971,762. August 28, 1934.
Sound reproducing apparatus. 1,978,183. October 23, 1934.
Colored television apparatus. 1,988,931. January 22, 1935.
System of distribution. 1,993,581. March 5, 1935.
High frequency transmission system for railways. 2,001,514. May 14, 1935.
Torque amplifying system. 2,027,140. January 7, 1936.
Airplane landing field using directional radio beams. 2,077,196. April 13, 1937. [With J. H. Hammond, Jr.]
Electric valve converting system. Reissue 20,364. May 18, 1937.
Electric power system. 2,084,177. June 15, 1937. [With A. H. Mittag.]

Electric valve translating circuit. 2,092,545. September 7, 1937.
Electric translating circuit. 2,092,546. September 7, 1937.
Electric valve translating circuits. 2,098,023. November 2, 1937.
Electric valve circuits. 2,104,633. January 4, 1938.
Electric valve converting system. 2,122,271. June 28, 1938.
Discharge lamp system. 2,135,268. November 1, 1938.
Cable for transmitting electric power. 2,141,894. December 27, 1938.
Course guiding system. 2,184,267. December 26, 1939.
Protective system for electric valve translating apparatus. 2,186,815. Jan. 9, 1940.
Electric valve circuit. 2,190,759. February 20, 1940.
Electric valve converting system. 2,193,912. March 19, 1940.
Electric valve frequency converting system. 2,193,913. March 19, 1940.
Electric valve frequency converting system. 2,193,914. March 19, 1940.
Asynchronous electric power transmission system. 2,207,570. July 9, 1940.
Electric power transmission system. 2,208,183. July 16, 1940.
Electric power transmission system. 2,213,945. September 10, 1940.
Excitation control system for synchronous machines. 2,215,312. Sep. 17, 1940.
Electric valve converting system and control circuit therefor. 2,215,313. September 17, 1940.
Protective system. 2,222,696. November 26, 1940.
Electric power converting apparatus. 2,225,328. December 17, 1940.
Dynamoelectric machine. 2,227,992. January 7, 1941. [With M. A. Edwards.]
Electric motor control system. 2,236,984. April 1, 1941.
Electric power system. 2,237,384. April 8, 1941.
Frequency controlling system. 2,239,436. April 22, 1941.
Electric transforming apparatus. 2,240,201. April 29, 1941.
Navigation and landing of aircraft in fog. 2,245,246. June 10, 1941.
Radio distance meter. 2,248,599. July 8, 1941.
Electric valve circuits. 2,248,600. July 8, 1941. [With A. H. Mittag.]
Speed regulating system. 2,256,463. September 23, 1941.
Electric valve circuit. Reissue. 21,919. October 14, 1941.
Radio distance meter. 2,259,982. October 21, 1941. [With F. G. Patterson and C. A. Nickle.]
Method of and apparatus for starting and operating thyratron motors. 2,262,482. November 11, 1941.
Electric motor control system. 2,285,182. June 2, 1942.
Electric drive. 2,312,061. February 23, 1943.
Electric drive. 2,312,062. February 23, 1943.
Electric drive. 2,315,489. April 6, 1943.
Electric drive. 2,315,490. April 6, 1943.
Electric drive. 2,315,491. April 6, 1943.
Speed control arrangement for induction clutches. 2,333,458. Nov. 2, 1943.
Television system and operation. 2,333,969. November 9, 1943.
Control circuit for electric valve apparatus. 2,343,628. March 7, 1944.
Electric valve translating system. 2,357,067. August 29, 1944.
Electric ship propulsion system. 2,357,087. August 29, 1944.
Control system. 2,401,450. June 4, 1946.
Control system. 2,412,027. December 3, 1946.

Follow-up control system. 2,414,685. January 21, 1947. [With M. A. Edwards and K. K. Bowman.]
Follow-up control system. 2,414,919. January 28, 1947.
Follow-up system. 2,416,562. February 25, 1947.
Electric computer. 2,417,229. March 11, 1947.
Electric control circuits. 2,431,903. December 2, 1947. [With A. H. Mittag.]
High-frequency wave transmitting apparatus. 2,438,735. March 30, 1948.
Electric frequency transformation system. 2,451,189. October 12, 1948. [With A. H. Mittag and M. W. Sims.]
Radio landing apparatus. 2,451,793. October 19, 1948. [With F. G. Patterson.]
Pulse echo apparatus for spotting shellfire. 2,463,233. March 1, 1949.
Stabilizer for alternating current power transmission systems. 2,470,454. May 17, 1949.
Follow-up control system. 2,473,235. June 14, 1949. [With M. A. Edwards and G. A. Hoyt.]
Radio detection and ranging system employing multiple scan. 2,526,314. October 17, 1950.
Fault-suppressing circuits. 2,548,577. April 10, 1951. [With A. H. Mittag and E. L. Phillipi.]
Locomotive power system. 2,549,405. April 17, 1951. [With B. D. Bedford and A. H. Mittag.]
System for reproducing positions. 2,550,514. April 24, 1951.
Electronic frequency changer and stabilizing control means therefor. 2,586,498. February 19, 1952.
Current interrupter. 2,612,629. September 30, 1952. [With A. H. Mittag and R. W. Kuenning.]
Electric motor and stabilizing means therefor. 2,640,179. May 26, 1953. [With S. P. Nixdorff.]
Stabilizer for alternating current power transmission systems. 2,644,898. July 7, 1953. [With R. W. Kuenning.]
Electronic motor and commutating means therefor. 2,644,916. July 7, 1953. [With S. P. Nixdorff.]
Phase balancing system. 2,652,529. September 15, 1953.
Receiver for color television. 2,701,821. February 8, 1955.
Alternating-current motor. 2,707,257. April 26, 1955.
Alternating-current motor. 2,711,502. June 21, 1955.
Magnetic amplifier motor control. 2,752,549. June 26, 1956.
System for controlling the flow of molten metal. 2,768,413. October 30, 1956.
Alternating-current motor. 2,797,375. June 25, 1957.
Push-pull magnetic amplifier. 2,798,904. July 9, 1957.
Magnetic amplifier motor control system. 2,844,779. July 22, 1958.
Methods and systems for motor control. 2,851,647. September 9, 1958.
Motor control system. 2,876,408. March 3, 1959.
Magnetic computer. 2,984,414. May 16, 1961.
Electric motor control apparatus. 3,050,672. August 21, 1962.
Electric motor control apparatus. 3,082,367. March 19, 1963.
Electric motor control system. 3,119,957. January 28, 1964.
Adjustable speed motor control system. 3,736,481. May 29, 1973.

Alexanderson Patents in Alphabetical Order

[See previous list for complete citations.]

Adjustable speed motor control system. 3,736,481.
Air-inlet valve for carbureters. 1,083,789.
Airplane landing field using directional radio beams. 2,077,196.
Alternating current commutator machine. 1,867,396.
Alternating-current-commutator motor. 1,194,923.
Alternating-current generator. 789,404; 789,476; 839,358.
Alternating-current high-frequency generator. 905,621.
Alternating-current motor. 841,610; 859,358; 873,702; 897,508; 923,753; 923,754; 927,398; 1,019,402; 1,060,731; 1,068,404; 1,194,265; 2,711,502; 2,797,375.
Alternating-current-motor control. 927,399; 946,751; 1,098,656; 1,603,102.
Amplifying electrical impulses. 1,906,441.
Amplifying system. 1,419,797.
Antenna. 1,360,167; 1,360,168; 1,677,698.
Apparatus for producing an electromotive force of special wave form. 1,250,752.
Apparatus for producing and distributing electric-current waves of radio frequency. 1,386,830.
Asynchronous electric power transmission system. 2,207,570.
Automatic control of phase-converters. 1,233,952.
Automatic control of phase-converters. Reissue. 14,510. August 27, 1918.
Automatic steering system. 1,958,258.
Bearing. 1,110,030; 1,315,069.
Boiler and heating arrangement therefor. 1,174,375.
Braking alternating-current motors. 967,295.
Cable for transmitting electric power. 2,141,894.
Circuit-control apparatus. 1,691,423.
Colored television apparatus. 1,988,931.
Commutator-motor. 949,992.
Compensated motor. 876,924.
Condenser. 1,266,377.
Control circuit for electric valve apparatus. 2,343,628.
Control of electric power. 1,655,036; 1,655,040; 1,719,866.
Control system. 1,461,571; 1,669,153; 1,787,299; 2,401,450; 2,412,027.
Controlling alternating currents. 1,206,643; 1,522,221; 1,634,970.
Cooling dynamo-electric machines. 1,382,878.
Course guiding system. 2,184,267.
Current interrupter. 2,612,629.
Discharge lamp system. 2,135,268.
Double-squirrel-cage synchronous motor. 1,495,969.
Dynamo-electric machine. 849,713; 861,072; 949,345; 1,091,613; 1,091,614; 1,092,420; 2,227,992.
Electric apparatus. 1,694,244.
Electric braking. 967,296; 974,224.
Electric braking with alternating-current motors. 1,089,384.
Electric computer. 2,417,229.
Electric control circuits. 2,431,903.

Starting motor-converter. 876,923.
Starting phase-converters. 1,300,545.
Surge preventer. 1,554,698.
Synchronous motor. 785,532; 897,507.
System for controlling the flow of molten metal. 2,768,413.
System for producing high frequency oscillations. 1,866,337.
System for reproducing positions. 2,550,514.
System of distribution. 1,537,055; 1,620,506; 1,680,758; 1,800,002; 1,835,131; 1,993,581.
System of electric distribution. 921,786.
System of electric power transmission. 1,917,081; 1,917,082.
System of electric ship propulsion. 1,289,593; 1,676,312.
System of electrical distribution. 1,150,652; 1,242,632; 1,375,991; 1,677,699; 1,677,700.
System of frequency transformation. 1,316,995.
System of motor control. 1,490,720.
System of phase modification. 1,300,543; 1,300,544.
System of radio communication. 1,400,847.
System of ship propulsion. 1,215,094; 1,215,095; 1,723,906.
Telephone-relay. 902,195.
Telephone relay and system. 996,445.
Telephone system. 1,102,628.
Television apparatus. 1,935,427.
Television receiver. 1,889,587.
Television system and operation. 2,333,969.
Torque amplifying system. 2,027,140.
Transmission of pictures. 1,694,302; 1,752,876; 1,783,031; 1,792,264; 1,830,586.
Transmitting angular motion. 1,600,204.
Two-speed winding for three-phase motors. 785,533.
Unidirectional radio receiving system. 1,465,108.
Voltage-regulator. 805,253; 829,826; 1,652,923.
Winding for three-phase motors. 785,995.
Wireless signaling system. 1,313,042; 1,350,911; 1,465,961; 1,465,962; 1,501,830; 1,508,151.
Wireless-telephone system. 1,313,041.

JOHN RENSHAW CARSON (1866-1940)

Patents In Chronological (Patent Number) Order

Duplex wireless system. 1,188,531. June 27, 1916. 227:1171.
Method of and means for transmitting signals. 1,243,705. Oct. 23, 1917. 243:808.
Wireless receiving system. 1,244,697. October 30, 1917. 243:1149.
Wireless signaling system. 1,309,459. July 8, 1919. 264:296.
Wireless system. 1,309,538. July 8, 1919. 264:311. [With John Mills.]
Translating-circuits. 1,312,433. August 5, 1919. 265:109.
Distortion-correcting circuit. 1,315,539. September 9, 1919. 266:204.
Duplex translating circuits. 1,343,306. June 15, 1920. 275:448.
Duplex translating circuits. 1,343,307. June 15, 1920. 275:448.

Duplex translating circuits. 1,343,308. June 15, 1920. 275:448.
Frequency-control system. 1,403,841. January 17, 1922.
Method of and means for modulating carrier oscillations. 1,410,890. Mar. 28, 1922.
Translating circuits. 1,448,702. March 13, 1923.
Method and means for signaling with high-frequency waves. 1,449,382. March 27, 1923.
Receiving circuits for weak signal currents. 1,450,969. April 10, 1923.
Single-side-band carrier-suppressed transmission. See 1,449,382.
Translating circuits. 1,463,795. August 7, 1923.
Translating circuits. 1,463,796. August 7, 1923.
Signaling system. 1,516,518. November 25, 1924.
Receiving weak signal currents. 1,532,172. April 7, 1925.
Telegraph signaling system. 1,559,159. October 27, 1925.
Loading system. 1,564,201. Dec. 8, 1925. [With A. B. Clark and John Mills.]
Translating circuit. 1,672,056. June 5, 1928.
Concentric conductor transmission system. 1,817,964. August 11, 1931. [With S. P. Mead.]

Carson Patents in Alphabetical Order

[See previous list for complete citations.]

Concentric conductor transmission system. 1,817,964.
Distortion-correcting circuit. 1,315,539.
Duplex translating circuits. 1,343,306; 1,343,307; 1,343,308.
Duplex wireless system. 1,188,531.
Frequency-control system. 1,403,841.
Loading system. 1,564,201.
Method and means for signaling with high-frequency waves. 1,449,382.
Method of and means for modulating carrier oscillations. 1,410,890.
Method of and means for transmitting signals. 1,243,705.
Receiving circuits for weak signal currents. 1,450,969.
Receiving weak signal currents. 1,532,172.
Signaling system. 1,516,518.
Telegraph signaling system. 1,559,159.
Translating circuit. 1,672,056.
Translating circuits. 1,312,433; 1,448,702; 1,463,795; 1,463,796.
Wireless receiving system. 1,244,697.
Wireless signaling system. 1,309,459.
Wireless system. 1,309,538.

EDWIN H. COLPITTS (1872-1949)

Patents in Chronological (Patent Number) Order

Magnetic core for inductance coils. 705,935. July 29, 1902. 100:1078. [With John C. Lee.]
Composite transmission over loaded electric circuits. 712,766. Nov. 4, 1902. 101:1010.
Connecting circuit for magneto telephone-exchange systems. 1,029,593. June 18, 1912. 179:587.

Electromagnetic coil. 1,116,020. November 3, 1914. 208:190.
Electric wave-amplifier. 1,128,292. February 16, 1915. 211:662.
System for amplifying electric waves. 1,129,959. March 2, 1915. 212:43.
System for the transmission of intelligence. 1,137,384. April 27, 1915. 213:1294.
System for measuring capacities. 1,167,677. January 11, 1916. 222:495. [With George A. Campbell and O. B. Blackwell.]
Multiplex radiotelegraph system. 1,194,820. August 15, 1916. 229:786.
Control device for wireless signaling. 1,198,699. September 19, 1916. 230:768.
Control device for wireless signaling. 1,198,700. September 19, 1916. 230:769.
Telephone transmission system. 1,200,082. October 3, 1916. 231:117.
System for the transmission of intelligence. Reissue. 14,380. Oct. 23, 1917. 243:1037.
Wireless telegraphy and telephony. 1,256,983. February 19, 1918. 247:624.
Signaling method and system. 1,375,675. April 26, 1921. 285:579.
Transmission of intelligence. 1,388,450. August 23, 1921. 289:676.
Control device for wireless signaling. Reissue. 15,538. February 13, 1923.
High-frequency signaling. 1,452,957. April 24, 1923.
Multiplex radiotelegraph system. 1,465,932. August 28, 1923.
Multiplex signaling system. 1,472,585. October 30, 1923.
Method of and apparatus for recording sound. 1,540,317. June 2, 1925. [With Edward B. Craft.]
Carrier-wave transmission. 1,573,303. February 16, 1926.
Oscillation generator. 1,624,537. April 12, 1927.

Colpitts Patents in Alphabetical Order

[See previous list for complete citations.]

Carrier-wave transmission. 1,573,303.
Composite transmission over loaded electric circuits. 712,766.
Connecting circuit for magneto telephone-exchange systems. 1,029,593.
Control device for wireless signaling. Reissue. 15,538. February 13, 1923.
Control device for wireless signaling. 1,198,699; 1,198,700.
Electric wave-amplifier. 1,128,292.
Electromagnetic coil. 1,116,020.
High-frequency signaling. 1,452,957.
Magnetic core for inductance coils. 705,935.
Method of and apparatus for recording sound. 1,540,317.
Multiplex radiotelegraph system. 1,194,820; 1,465,932.
Multiplex signaling system. 1,472,585.
Oscillation generator. 1,624,537.
Signaling method and system. 1,375,675.
System for amplifying electric waves. 1,129,959.
System for measuring capacities. 1,167,677.
System for the transmission of intelligence. 1,137,384.
System for the transmission of intelligence. Reissue. 14,380. October 23, 1917.
Telephone transmission system. 1,200,082.
Transmission of intelligence. 1,388,450.
Wireless telegraphy and telephony. 1,256,983.

HARRY P. DAVIS (1868-1931)
Patents in Chronological (Patent Number) Order

Controlling switch for electrically-propelled vehicles. 503,279. Aug. 15, 1893. 64:913.
Resistance-coil. 513,457. January 23, 1894. 66:641.
Method of and means for controlling electric cars. 527,947. Oct. 23, 1894. 69:438.
Automatic-circuit breaker. 532,537. January 15, 1895. 70:316.
Controller for electric cars. 532,538. January 15, 1895. 70:317.
Non-arcing switch. 532,594. January 15, 1895. 70:334. [With Charles F. Scott.]
Electric-arc lamp. 535,051. March 5, 1895. 70:1224.
Electric-arc lamp. 535,052. March 5, 1895. 70:1224.
Combined insulator and fuse-holder. 541,459. June 25, 1895. 71:1776. [With C. F. Scott.]
Fuse-block. 541,473. June 25, 1895. 71:1782. [With C. F. Scott.]
Rheostat element. 548,867. October 29, 1895. 73:726.
Rheostat 559,685. May 5, 1896. 75:790.
Electric-arc lamp. 569,817. October 20, 1896. 77:393.
Electric-arc lamp. 569,818. October 20, 1896. 77:393.
Controller for electric motors. 574,885. January 12, 1897. 78:184.
Supporting means for electric-railway supply-conductors. 580,380. April 13, 1897. 79:172.
Supporting means for electric-railway supply-conductors. 580,381. April 13, 1897. 79:172.
Controller for electric cars. 582,102. May 4, 1897. 79:830. [With Albert Schmid.]
Controller for electric motors. 582,114. May 4, 1897. 79:836.
Method of and means for controlling electric motors. 582,115. May 4, 1897. 79:837.
Controller for electric motors. 584,856. June 22, 1897. 79:1900.
Quick-break switch. 599,929. March 1, 1898. 82:1304.
Switch for electric circuits. 599,930. Mar. 1, 1898. 82:1304. [With E. F. Harder.]
Electric-arc lamp. 599,931. March 1, 1898. 82:1305.@
Contact device for electrically-propelled vehicles. 606,819. July 5, 1898. 84:68.
Current-collecting apparatus for electric railways. 606,826. July 5, 1898. 84:72. [With Charles A. Terry.]
Overhead construction for electric railways. 606,827. July 5, 1898. 84:72. [With Charles A. Terry.]
Electric brake. 606,917. July 5, 1898. 84:99.
Regulating-switch for electric circuits. 607,617. July 19, 1898. 84:425. [With G. Wright.]
Electric meter and motor. 608,842. August 9, 1898. 84:914.@
Controller for electric motors. 610,124. August 30, 1898. 84:1414.
Controller for electric motors. 611,465. September 27, 1898. 84:1961.
Alternating-current-measuring instrument. 611,466. September 27, 1898. 84:1962. @
Alternating-current voltmeter. 611,592. September 27, 1898. 84:2007.@

@ With Frank Conrad.

Circuit-breaker. 622,885. April 11, 1899. 87:260.
Controller for electric motors. 625,151. May 16, 1899. 87:1162. [With G. Wright.]
Electrical measuring instrument. 627,908. June 27, 1899. 87:2288. @
Fuse-block for electric circuits. 629,663. July 25, 1899. 88:673.
High-tension circuit-breaker. 629,664. July 25, 1899. 88:674. [With G. Wright.]
Controller for electric motors. 629,665. July 25, 1899. 88:674. [With G. Wright.]
Fuse-block. 644,850. March 6, 1900. 90:1862.
Switch for electric circuits. 685,507. October 29, 1901. 97:868.
Resistance-coil and support therefor. 710,143. September 30, 1902. 100:2901.
Controlling induction-motors. 725,681. April 21, 1903. 103:1698.
High-tension-circuit breaker. 758,621. May 3, 1904. 110:10.
Strain device for electric railways. 791,012. May 30, 1905. 116:1243. +
Supporting and strain device for electric railways. 791,013. May 30, 1905. 116:1243. +
Trolley-wire hanger. 791,082. May 30, 1905. 116:1272. +
Curve pull-off for overhead trolley-conductors. 791,083. May 30, 1905. 116:1272. +
Circuit-breaker. 797,048. August 15, 1905. 117:1830. [With A. B. Reynders.]
Circuit-breaker. 798,171. August 29, 1905. 117:2416.
Trolley and trolley-support. 801,225. October 10, 1905. 118:1386. [With C. Aalborg.]
Trolley for electric-railway vehicles. 801,226. October 10, 1905. 118:1387. [With C. Aalborg.]
Overhead structure for electric railways. 803,215. Oct. 31, 1905. 118:2360. +
Suspension device for trolley-conductors. 803,216. Oct. 31, 1905. 118:2360. +
Protective apparatus for electrical circuits. 840,478. Jan. 8, 1907. 126:404. @
Protective apparatus for parallel transmission-lines. 840,479. Jan. 8, 1907. 126:404. @
Transformer. 841,076. January 8, 1907. 126:700. @
Strain-insulator. 861,094. July 23, 1907. 129:1507.
Indicating means for instruments. 920,927. May 11, 1909. 142:303. [With P. MacGahan.]
Trolley-clamp. 931,390. August 17, 1909. 145:647.
Trolley-clamp. 931,391. August 17, 1909. 145:647.
Trolley-hanger. 931,392. August 17, 1909. 145:647.
Trolley-conductor hanger. 931,393. August 17, 1909. 145:648.
Trolley. 932,538. August 31, 1909. 145:1067. +
Overhead-line material for electrical railways. 933,747. Sep. 14, 1909. 146:266
Electric-line construction. 946,537. Jan. 18, 1910. 150:578. +
Explosion circuit-breaker. 1,009,386. Nov. 21, 1911. 172:683. [With F. W. Harris.]
Supporting structure for trolley-conductors. 1,076,630. Oct. 21, 1913. 195:761. +
Circuit-interrupter. 1,123,255. January 5, 1915. 210:18. [With C. Aalborg.]
System of electrical distribution. 1,138,637. May 11, 1915. 214:358. @
Circuit-interrupter. 1,140,961. May 25, 1915. 214:1248. [With C. Aalborg.]
System of electrical distribution. 1,159,904. November 9, 1915. 220:558. @
Hand-grenade. 1,303,260. May 13, 1919. 262:177.
Tube connector. 1,768,669. July 1, 1930.

+ With Theodore Varney.

Davis Patents in Alphabetical Order

[See previous list for complete citations.]

Alternating-current-measuring instrument. 611,466.
Alternating-current voltmeter. 611,592.
Automatic-circuit breaker. 532,537.
Circuit-breaker. 622,885; 797,048; 798,171.
Circuit-interrupter. 1,123,255; 1,140,961.
Combined insulator and fuse-holder. 541,459.
Contact device for electrically-propelled vehicles. 606,819.
Controller for electric cars. 532,538; 582,102.
Controller for electric motors. 574,885; 582,114; 584,856; 610,124; 611,465; 625,151.
Controlling induction-motors. 725,681.
Controlling switch for electrically-propelled vehicles. 503,279.
Current-collecting apparatus for electric railways. 606,826.
Curve pull-off for overhead trolley-conductors. 791,083.
Electric-arc lamp. 535,051; 535,052; 569,817; 569,818; 599,931.
Electric brake. 606,917.
Electric-line construction. 946,537.
Electric meter and motor. 608,842.
Electrical measuring instrument. 627,908.
Explosion circuit-breaker. 1,009,386.
Fuse-block. 541,473; 644,850.
Fuse-block for electric circuits. 629,663.
Hand-grenade. 1,303,260.
High-tension circuit-breaker. 629,664; 758,621.
Indicating means for instruments. 920,927.
Method of and means for controlling electric cars. 527,947.
Method of and means for controlling electric motors. 582,115.
Non-arcing switch. 532,594.
Overhead construction for electric railways. 606,827.
Overhead-line material for electrical railways. 933,747.
Overhead structure for electric railways. 803,215.
Protective apparatus for electrical circuits. 840,478.
Protective apparatus for parallel transmission-lines. 840,479.
Quick-break switch. 599,929.
Regulating-switch for electric circuits. 607,617.
Resistance-coil. 513,457.
Resistance-coil and support therefor. 710,143.
Rheostat. 559,685.
Rheostat element. 548,867.
Strain device for electric railways. 791,012.
Strain-insulator. 861,094.
Supporting and strain device for electric railways. 791,013.
Supporting means for electric-railway supply-conductors. 580,380; 580,381.
Supporting structure for trolley-conductors. 1,076,630.
Suspension device for trolley-conductors. 803,216.
Switch for electric circuits. 599,930; 685,507.

System of electrical distribution. 1,138,637; 1,159,904.
Transformer. 841,076.
Trolley. 932,538.
Trolley and trolley-support. 801,225.
Trolley-clamp. 931,390; 931,391.
Trolley-conductor hanger. 931,393.
Trolley for electric-railway vehicles. 801,226.
Trolley-hanger. 931,392.
Trolley-wire hanger. 791,082.
Tube connecter. 1,768,669.

HUGO GERNSBACK (1884-1967)
Patents in Chronological (Patent Number) Order

Battery-cell. 842,950. February 5, 1907. 126:1843.
Incandescent lamp. 902,069. October 27, 1908. 136:1819.
Electrorheostat-regulator. 948,275. February 1, 1910. 151:166.
Electro-adjustable condenser. 951,788. March 8, 1910. 152:464.
Detectorium. 961,855. June 21, 1910. 155:596.
Relay. 978,999. December 20, 1910. 161:600.
Potentiometer. 988,456. April 4, 1911. 165:57.
Electrolytic interrupter. 988,767. April 4, 1911. 165:164.
Combined electric hair brush and comb. 1,016,138. January 30, 1912. 174:1161.
Rotary variable condenser. 1,033,095. July 23, 1912. 180:894.
Luminous electric mirror. 1,057,820. April 1, 1913. 189:146.
Transmitter. 1,124,413. January 12, 1915. 210:466.
Postal card. 1,209,425. December 19, 1916. 233:1003.
Telephone-headband. 1,329,658. February 3, 1920. 271:58.
Electromagnetic sending device. 1,354,389. September 28, 1920. 278:667.
Submersible amusement device. 1,384,750. July 19, 1921. 288:440.
Apparatus for landing flying-machines. 1,392,140. September 27, 1921. 290:748.
Tuned telephone receiver. 1,478,709. December 25, 1923.
Electric valve. 1,488,337. March 25, 1924.
Detector. 1,496,671. June 3, 1924.
Ear cushion. 1,514,152. November 4, 1924.
Acoustic apparatus. 1,521,287. December 30, 1924.
Radiocabinet. Design 67,451. June 2, 1925.
Radiocabinet. Design 67,452. June 2, 1925.
Cord terminal. 1,557,248. October 13, 1925.
Coil mounting. 1,558,604. October 27, 1925.
Radiohorn. 1,560,684. November 10, 1925.
Variable condenser. 1,562,629. November 24, 1925.
Electrical switch. 1,585,485. May 18, 1926.
Telephone receiver. 1,587,719. June 8, 1926.
Crystal detector. 1,590,236. June 29, 1926.
Mounting inductances. 1,618,002. February 15, 1927.
Depilator. 1,620,539. March 8, 1927.
Switch. 1,695,957. December 18, 1928.

Code learner's instrument. 1,801,734. April 21, 1931.
Electrically operated fountain. 1,954,704. April 10, 1934. [With Joseph H. Kraus and S. Gernsback.]
Hydraulic fishery. 2,718,083. September 20, 1955.

Gernsback Patents in Alphabetical Order

[See previous list for complete citations.]

Acoustic apparatus. 1,521,287.
Apparatus for landing flying-machines. 1,392,140.
Battery-cell. 842,950.
Code learner's instrument. 1,801,734.
Coil mounting. 1,558,604.
Combined electric hair brush and comb. 1,016,138.
Cord terminal. 1,557,248.
Crystal detector. 1,590,236.
Depilator. 1,620,539.
Detector. 1,496,671.
Detectorium. 961,855.
Ear cushion. 1,514,152.
Electric valve. 1,488,337.
Electrical switch. 1,585,485.
Electrically operated fountain. 1,954,704.
Electro-adjustable condenser. 951,788.
Electrolytic interrupter. 988,767.
Electromagnetic sending device. 1,354,389.
Electrorheostat-regulator. 948,275.
Hydraulic fishery. 2,718,083.
Incandescent lamp. 902,069.
Luminous electric mirror. 1,057,820.
Mounting inductances. 1,618,002.
Postal card. 1,209,425.
Potentiometer. 988,456.
Radiocabinet. Design 67,451; 67,452. June 2, 1925.
Radiohorn. 1,560,684.
Relay. 978,999.
Rotary variable condenser. 1,033,095.
Submersible amusement device. 1,384,750.
Switch. 1,695,957.
Telephone-headband. 1,329,658.
Telephone receiver. 1,587,719.
Transmitter. 1,124,413.
Tuned telephone receiver. 1,478,709.
Variable condenser. 1,562,629.

JOHN V. L. HOGAN (1890-1960)

Patents in Chronological (Patent Number) Order

Detector for wireless communication. 950,781. March 1, 1910. 152:110.

Apparatus for wireless signaling. 1,014,002. January 9, 1912. 174:345.
Break-key. 1,016,564. February 6, 1912. 175:114.
Transmitting intelligence by radiant energy. 1,141,717. June 1, 1915. 215:223. [With John W. Lee, S. M. Kintner, and H. M. Barrett.]
Oscillating-current meter. 1,152,632. September 7, 1915. 218:93. [With S. M. Kintner and H. M. Barrett.]
Radiosignaling. 1,350,100. August 17, 1920. 277:508.
Receiver for wireless telegraphy. 1,363,319. December 28, 1920. 281:600. [With S. M. Kintner and H. M. Barrett.]
Demountable rim. 1,389,345. August 30, 1921. 289:906. [With Thomas E. Dunbar and H. Crevasse.]
Arc transmission system. 1,537,609. May 12, 1925.
Acoustic device. 1,776,223. September 16, 1930.
Television method and apparatus. 1,943,238. Jan. 9, 1934. [With H. P. Donle.]
Television transmission. 1,976,699. October 9, 1934.
Television scanning system. 1,994,708. March 19, 1935.
Television synchronization. 1,998,812. April 23, 1935.
Scanning system. 2,010,764. August 8, 1935.
System for television and sound. 2,049,384. July 28, 1936.
Recording paper system. 2,111,776. March 22, 1938.
Facsimile system. 2,149,292. March 7, 1939. [With H. G. Miller.]
Means and method for facsimile recording. 2,173,113. Sept. 19, 1939. [With H. G. Miller.]
Facsimile recorder. 2,202,855. June 4, 1940. [With H. C. Ressler.]
Cathode ray system. 2,212,640. August 27, 1940.
Facsimile apparatus. 2,239,489. April 22, 1941. [With H. G. Miller.]
Electrolytic recording. 2,339,267. January 18, 1944. [With H. C. Ressler.]
Facsimile scanner drum. 2,356,999. August 29, 1944.
Registering radio listening habits. 2,368,761. February 6, 1945.
Facsimile apparatus. 2,379,438. July 3, 1945.
Continuous facsimile scanner. 2,379,906. July 10, 1945.
Graphic privacy system. 2,414,101. January 14, 1947. [With H. C. Ressler.]
Graphic privacy system. 2,437,255. March 9, 1948. [With H. C. Ressler.]
Facsimile recorder construction. 2,575,959. November 20, 1951.
Quantity recorder. 2,587,319. February 26, 1952.

Hogan Patents in Alphabetical Order

[See previous list for complete citations.]

Acoustic device. 1,776,223.
Apparatus for wireless signaling. 1,014,002.
Arc transmission system. 1,537,609.
Break-key. 1,016,564.
Cathode ray system. 2,212,640.
Continuous facsimile scanner. 2,379,906.
Demountable rim. 1,389,345.
Detector for wireless communication. 950,781.
Electrolytic recording. 2,339,267.

Facsimile apparatus. 2,239,489; 2,379,438.
Facsimile recorder. 2,202,855.
Facsimile recorder construction. 2,575,959.
Facsimile scanner drum. 2,356,999.
Facsimile system. 2,149,292.
Graphic privacy system. 2,414,101; 2,437,255.
Means and method for facsimile recording. 2,173,113.
Oscillating-current meter. 1,152,632.
Quantity recorder. 2,587,319.
Radiosignaling. 1,350,100.
Receiver for wireless telegraphy. 1,363,319.
Recording paper system. 2,111,776.
Registering radio listening habits. 2,368,761.
Scanning system. 2,010,764.
Single dial tuning. See 1,014,002.
System for television and sound. 2,049,384.
Television method and apparatus. 1,943,238.
Television scanning system. 1,994,708.
Television synchronization. 1,998,812.
Television transmission. 1,976,699.
Transmitting intelligence by radiant energy. 1,141,717.

MAHLON LOOMIS (1826-1886)

Plates for artificial teeth. 10,847. May 2, 1854.
Plate for artificial teeth. (Extension). April 8, 1868.
Telegraphing. 129,971. July 30, 1872. 2:183.
Convertible valise. 241,387. May 10, 1881. 19:1197.
Cuff and collar fastening. 250,268. November 29, 1881. 20:1573.
Electrical thermostat. 338,090. March 16, 1886. 34:1232.

MICHAEL I. PUPIN (1858-1935)

Patents in Chronological (Patent Number) Order

Apparatus for telegraphic or telephonic transmission. 519,346. May 8, 1894. 67:696.
Transformer for telegraphic, telephonic, or other electrical systems. 519,347. May 8, 1994. 67:697.
Distributing electrical energy by alternating currents. 640,515. Jan. 2, 1900. 90:133.
Electrical transmission by resonance-circuits. 640,516. January 2, 1900. 90:134.
Reducing attenuation of electrical waves and apparatus therefor. 652,230. June 19, 1900. 91:2361.
Reducing attenuation of electrical waves. 652,231. June 19, 1900. 91:2362.
Winding-machine. 697,660. April 15, 1902. 99:535. [With S. W. Balch.]
Multiple telegraphy. 707,007. August 12, 1902. 100:1525.
Multiple telegraphy. 707,008. August 12, 1902. 100:1525.
Producing asymmetrical currents from symmetrical alternating electromotive forces. 713,044. November 4, 1902. 101:1116.
Apparatus for producing asymmetrical currents from symmetrical alternating

electromotive forces. 713,045. November 4, 1902. 101:1116.
Apparatus for reducing attenuation of electrical waves. 761,995. June 7, 1904. 110:1602.
Wireless electrical signaling. 768,301. August 23, 1904. 111:2076.
Telegraphy. 821,741. May 29, 1906. 122:1465.
Electric-wave transmission. 1,334,165. March 16, 1920. 272:489. [With E. H. Armstrong.]
Antenna with distributed positive resistance. 1,336,378. April 6, 1920. 273:127.
Multiple antenna for electrical wave transmission. 1,388,441. August 23, 1921. 289:674. [With E. H. Armstrong.]
Sound-generator. 1,399,877. December 13, 1921.
Selectively opposing impedance to received electrical oscillations. 1,415,845. May 9, 1922. [With E. H. Armstrong.]
Radioreceiving system having high selectivity. 1,416,061. May 16, 1922. [With E. H. Armstrong.]
Aperiodic pilot conductor. 1,446,769. February 27, 1923. [With M. C. Spencer.]
Selective amplifying apparatus. 1,452,833. April 24, 1923.
Wave conductor. 1,456,909. May 29, 1923.
Selective amplifying apparatus. 1,488,514. January 1, 1924.
Electrical tuning. 1,494,803. May 20, 1924.
Tone-producing radioreceiver. 1,502,875. July 29, 1924. [With E. H. Armstrong.]
Electrical wave transmission. 1,541,845. June 16, 1925.
Wave signaling system. 1,561,278. November 10, 1925.
Equalizing vacuum-tube amplifier. 1,561,279. November 10, 1925.
Electromagnetic production of direct current without fluctuations. 1,571,458. February 2, 1926.
Electrical pulse generator. 1,657,587. January 31, 1928.
Telegraph system. 1,811,368. June 23, 1931.
Inductive artificial line. 1,834,735. December 1, 1931.
Supply system for vacuum tubes. 1,983,774. December 11, 1934.

Pupin Patents in Alphabetical Order

[See previous list for complete citations.]

Antenna with distributed positive resistance. 1,336,378.
Aperiodic pilot conductor. 1,446,769.
Apparatus for producing asymmetrical currents from symmetrical alternating electromotive forces. 713,045.
Apparatus for reducing attenuation of electrical waves. 761,995.
Apparatus for telegraphic or telephonic transmission. 519,346.
Distributing electrical energy by alternating currents. 640,515.
Electric-wave transmission. 1,334,165.
Electrical pulse generator. 1,657,587.
Electrical transmission by resonance-circuits. 640,516.
Electrical tuning. 1,494,803.
Electrical wave transmission. 1,541,845.
Electromagnetic production of direct current without fluctuations. 1,571,458.
Equalizing vacuum-tube amplifier. 1,561,279.

Inductive artificial line. 1,834,735.
Multiple antenna for electrical wave transmission. 1,388,441.
Multiple telegraphy. 707,007; 707,008.
Producing asymmetrical currents from symmetrical alternating electromotive forces. 713,044.
Radioreceiving system having high selectivity. 1,416,061.
Reducing attenuation of electrical waves. 652,231.
Reducing attenuation of electrical waves and apparatus therefor. 652,230.
Selective amplifying apparatus. 1,452,833; 1,488,514.
Selectively opposing impedance to received electrical oscillations. 1,415,845.
Sound-generator. 1,399,877.
Supply system for vacuum tubes. 1,983,774.
Telegraph system. 1,811,368.
Telegraphy. 821,741.
Tone-producing radioreceiver. 1,502,875.
Transformer for telegraphic, telephonic, or other electrical systems. 519,347.
Wave conductor. 1,456,909.
Wave signaling system. 1,561,278.
Winding-machine. 697,660.
Wireless electrical signaling. 768,301.

JOHN F. RIDER (1900-1985)

Switching device for radio receiving and other electrical systems. 2,064,348. December 15, 1936. [With Paul Kalencik.]
Measurement of electrical constants of tuned circuits. 2,111,235. March 15, 1938. [With Jack Avins.]
Electrical testing system. 2,227,381. December 31, 1940. [With Jack Avins.]
Multisection book. 2,308,628. January 19, 1943.
Oscillator for sine waves and square waves. 2,346,396. April 11, 1944.
Unitary volume-control switch and dialite assembly. 2,457,920. January 4, 1949.
Single button tuning control for radio sets. 2,487,760. November 8, 1949. [With Richard F. Koch.]
Composite test probe for radio apparatus and the like. 2,488,328. Nov. 15, 1949.

JOHN STONE STONE (1869-1943)

Patents in Chronological (Patent Number) Order

Electric cable. 469,475. Feb. 23, 1892. 58:1029. [With Hammond V. Hayes.]
Development and distribution of electricity. 487,102. Nov. 29, 1892. 61:1262.
Telephone-circuit. 507,568. October 31, 1893. 65:621.
Telephone-transmitter circuit and apparatus. 507,694. Oct. 31, 1893. 65:661.
Telephone-circuit. 508,255. November 7, 1893. 65:842.
Telephonic transmission. 509,965. December 5, 1893. 65:1446.
Telephone circuit. 551,060. December 10, 1895. 73:1596.
Telephone circuit. 553,179. January 14, 1896. 74:251. [With Edward Slade.]
Telephone speaking-tube system. 556,034. March 10, 1896. 74:1328.
Telephone circuit. 560,761. May 26, 1896. 75:1247.
Telephone circuit and apparatus. 560,762. May 26, 1896. 75:1248.

System of current supply for telephone-circuits. 562,435. June 23, 1896. 75:1882.
Telephone signaling-circuit. 563,692. July 7, 1896. 76:144.
Resonant electric circuit. 577,214. February 16, 1897. 78:1032.
Electric circuit. 578,275. March 2, 1897. 78:1408.
Telephone circuit. 580,166. April 6, 1897. 79:87.
Telephone repeater or relay. 609,374. August 16, 1898. 84:1121.
Differential electromagnet. 623,579. April 25, 1899. 87:547.
Telephony. 638,152. November 28, 1899. 89:1825.
Selective electric signaling. 714,756. December 2, 1902. 101:1878.*
Apparatus for selective electric signaling. 714,831. Dec. 2, 1902. 101:1906.*
Apparatus for amplifying electromagnetic signal-waves. 714,832. December 2, 1902. 101:1910.*
Amplifying electromagnetic signal-waves. 714,833. Dec. 2, 1902. 101:1910.*
Apparatus for selective electric signaling. 714,834. Dec. 2, 1902. 101:1910.*
Determining the direction of space-telegraph signals. 716,134. December 16, 1902. 101:2470.*
Apparatus for determining the direction of space-telegraph signals. 716,135. December 16, 1902. 101:2470.*
Apparatus for simultaneously transmitting and receiving space-telegraph signals. 716,136. December 16, 1902. 101:2470.*
Simultaneously transmitting and receiving space-telegraph signals. 716,137. December 16, 1902. 101:2470.*
Simultaneously transmitting and receiving space-telegraph signals. 716,955. December 30, 1902. 101:2870.*
Electrical distribution. 717,467. December 30, 1902. 101:3073.
Apparatus for relaying space-telegraph signals. 717,509. December 30, 1902. 101:3089.*
Relaying space-telegraph signals. 717,510. December 30, 1902. 101:3089.*
Tuning vertical wire oscillators. 717,511. December 30, 1902. 101:3089.*
Tuned electric oscillator. 717,512. December 30, 1902. 101:3089.*
Relaying space-telegraph signals. 717,513. December 30, 1902. 101:3090.*
Apparatus for relaying space-telegraph signals. 717,514. Dec. 30, 1902. 101:3090.*
Electrical distribution. 717,515. December 30, 1902. 101:3090.
Wireless or space telegraphy. 725,634. April 14, 1903. 103:1664.
Space telegraphy. 725,635. April 14, 1903. 103:1665
Space telegraphy. 725,636. April 14, 1903. 103:1666.
Electrical distribution and selective distribution. 726,368. April 28, 1903. 103:1976
Electrical distribution and selective distribution. 726,476. April 28, 1903. 103:2016.
Electrical distribution and selective distribution. 729,103. May 26, 1903. 104:956.
Electrical apparatus and circuits for electrical distribution and selective distribution. 729,104. May 26, 1903. 104:957.
Apparatus for selective electric signaling. Reissue. 12,141. Aug. 4, 1903. 105:1249.
Apparatus for selective electric signaling. 737,170. August 25, 1903. 105:1880.
Determining the direction of space-telegraph signals. Reissue. 12,148. August 18, 1903. 105:1766.
Apparatus for selective electrical signaling. Reissue. 12,149. August 25, 1903.

105:2044.
Apparatus for amplifying electromagnetic signal-waves. Reissue. 12,151. September 8, 1903. 106:530.
Amplifying electromagnetic signal-waves. Reissue. 12,152. Sep. 8, 1903. 106:530.
Apparatus for simultaneously transmitting and receiving space-telegraph signals. 767,970. August 16, 1904. 111:1891.
Wireless-telegraph receiving device. 767,971. August 16, 1904. 111:1893.
Receiving space-telegraph signals. 767,972. August 16, 1904. 111:1895.
Increasing the effective radiation of electromagnetic waves. 767,973. August 16, 1904. 111:1896. [With W. W. Swan, trustee.]
Apparatus for increasing the effective radiation of electromagnetic waves. 767,974. August 16, 1904. 111:1897. [With W. W. Swan, trustee.]
Space telegraphy. 767,975 through 768,005. August 16, 1904. 111:1897 through 1918. [All with W. W. Swan, trustee.]
Protecting telephone-circuits from the action of electromagnetic waves. 781,625. January 31, 1905. 114:1250.
Space telegraphy. 802,417 through 802,432. October 24, 1905. 118:1962 through 1970. [W. W. Swan, trustee.]
Space telephony. 803,199. October 31, 1905. 118:2353.
Space telephony. 803,513. October 31, 1905. 118:2485.
Device for amplifying electrical currents. 854,120. May 21, 1907. 128:981.
Space telegraphy. 864,272. August 27, 1907. 129:3227.
Space telegraphy. 884,106 through 884,109. Apr. 7, 1908. 133:1334 through 1335.#
Space telegraphy. 884,110. April 7, 1908. 133:1336. [With S. Cabot; Assignors to W. W. Swan, trustee.]
Apparatus for determining the direction of space-telegraph signals. 899,272. September 22, 1908. 136:748.#
Condenser. 908,814. January 5, 1909. 138:125.
Space telegraphy. 908,815. January 5, 1909. 138:125.
Space telegraphy. 916,895. March 30, 1909. 140:1166.
Space telegraphy. 946,166 through 946,168. January 11, 1910. 150:424.
Apparatus for determining the direction of space-telegraph signals. 961,265. June 14, 1910. 155:373.
Space telegraphy. 986,651. March 14, 1911. 164:336.
Resistance amplifier. 1,555,037. September 29, 1925.
Secret-communication system. 1,565,521. Dec. 15, 1925. [With C. C. Rose.]
Carrier-current multiplex signaling system. 1,565,522. December 15, 1925.
Radio transmitting system. 1,567,204. December 29, 1925.
Thermionic modulator. 1,573,282. February 16, 1926.
Amplifier. 1,590,263. June 29, 1926.
Multiplex radio telegraphy and telephony. 1,598,663. September 7, 1926.
Signaling system. 1,605,010. November 2, 1926.
Circuits for passing or stopping a frequency band of alternating currents. 1,610,336. December 14, 1926.
Directive antenna array. 1,643,323. September 27, 1927.
Reactance neutralizing network. 1,674,705. June 26, 1928.
Directive antenna array. 1,683,739. September 11, 1928.
Antenna array. 1,715,433. June 4, 1929.

Associated resonant circuits. 1,720,770. July 16, 1929.
Radio receiving system. 1,789,419. January 20, 1931.
Directional antenna array. 1,808,867. June 9, 1931.
Directional antenna array. 1,808,868. June 9, 1931.
Directional antenna array. 1,808,869. June 9, 1931.
Advertising device. 1,822,511. September 8, 1931. [With G. Wilson.]
Valve commutator and its use in multiplex signaling. 1,835,099. Dec. 8, 1931.
Time switch. 1,893,904. January 10, 1933. [With John B. Petrus.]
Apparatus and method for radio transmission and reception. 1,919,309. June 25, 1933.
Antenna array. 1,922,115. August 15, 1933.
Antenna array. 1,922,116. August 15, 1933.
Sound amplifier. 1,929,569. October 10, 1933.
Radioantenna. 1,941,636. January 2, 1934.
Radio receiving system. 1,954,898. April 17, 1934.
Reenforced soap cake. 1,997,474. April 9, 1935.
Frequency selective communication system. 2,023,556. December 10, 1935.
Composite oscillator for electromagnetic waves. 2,026,712. January 7, 1936.
Radio receiving system. 2,037,154. April 14, 1936.
Condenser telephone transmitter circuit. 2,232,891. February 25, 1941.
Frequency sensitive elements. 2,301,828. November 10, 1942.

* [Assignor to L. E. Whicher, A. P. Browne, and B. T. Judkins, trustees.]
# [Assignor to W. W. Swan, trustee.]

Stone Patents in Alphabetical Order

[See previous list for complete citations.]

Advertising device. 1,822,511.
Amplifier. 1,590,262.
Amplifying electromagnetic signal-waves. Reissue. 12,152. September 8, 1903.
Amplifying electromagnetic signal-waves. 714,833.
Antenna array. 1,715,433; 1,922,115; 1,922,116.
Apparatus and method for radio transmission and reception. 1,919,309.
Apparatus for amplifying electromagnetic signal-waves. 714,832.
Apparatus for amplifying electromagnetic signal-waves. Reissue. 12,151. September 8, 1903.
Apparatus for determining the direction of space-telegraph signals. 716,135; 899,272; 961,265.
Apparatus for increasing the effective radiation of electromagnetic waves. 767,974.
Apparatus for relaying space-telegraph signals. 717,509; 717,514.
Apparatus for selective electric signaling. 714,831; 714,834; 737,170.
Apparatus for selective electric signaling. Reissue. 12,141. August 4, 1903.
Apparatus for selective electrical signaling. Reissue. 12,149. August 25, 1903.
Apparatus for simultaneously transmitting and receiving space-telegraph signals. 716,136; 767,970.
Associated resonant circuits. 1,720,770.
Carrier-current multiplex signaling system. 1,565,522.
Circuits for passing or stopping a frequency band of alternating currents. 1,610,336.

Telephonic transmission. 509,965.
Telephony. 638,152.
Thermionic modulator. 1,573,282.
Time switch. 1,893,904.
Tuned electric oscillator. 717,512.
Tuning vertical wire oscillators. 717,511.
Valve commutator and its use in multiplex signaling. 1,835,099.
Wireless or space telegraphy. 725,634.
Wireless-telegraph receiving device. 767,971.

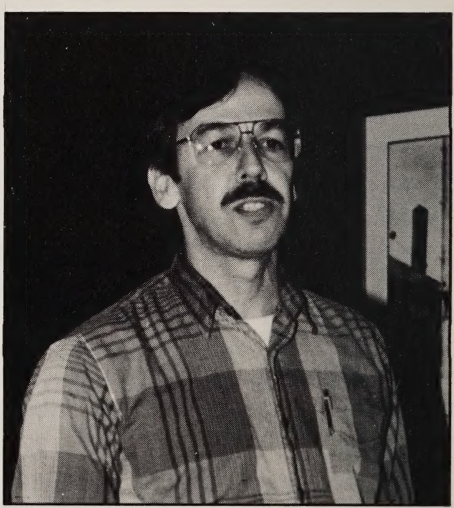
NATHAN B. STUBBLEFIELD (1860?-1928)

Lighting device. 329,864. November 3, 1885. 33:616.
Mechanical telephone. 378,183. Feb. 21, 1888. 42:758. [With S. C. Holcomb.]
Electrical battery. 600,457. March 8, 1898. 82:1528. [With W. G. Love.]
Wireless telephone. 887,357. May 12, 1908. 134:365. [Assignor of 12-½/100 to C. Linn, 5/100 to R. Downs, 5/100 to B. F. Schroader, 5/100 to G. C. McLarin, 5/100 to J. P. McElrath, 2-½/100 to J. D. Roulett, and 1/20 to S. E. Bynum, Murray, Ky.]

HOW TO GET COPIES OF PATENTS

Copies of patents may be ordered from the Commissioner of Patents and Trademarks, Washington, D.C. 20231. Copies are $1.50 per patent postpaid, and should be ordered by patent number. Patents may also be consulted and photocopied at Patent Depository Libraries listed on pages 189-190 of AWA Review, Vol. 5.

David W. Kraeuter



David W. Kraeuter was born in Pittsburgh in 1941. He has been tinkering with and sometimes repairing electronic equipment since he was in grade school. Since 1985 his articles on the personal and whimsical side of radio history have appeared in "Antique Radio Classified." In 1986 he became a founding member and officer of the Pittsburgh Antique Radio Society and has edited the Society's newsletter, "The Pittsburgh Oscillator," since then. He is also the compiler of A Bibliography of Frank Conrad, which is available from the Society. He now plans to assemble a list of patents of the "third layer" of radio inventors. He has been a reference librarian at Washington and Jefferson College in Washington, PA, since earning a Master of Library Science degree from the University of Pittsburgh in 1968.